# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

OF

# CIVIL ENGINEERS.

(INSTITUTED 1852.)

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VOL. XXXII. No. 1.

JANUARY, 1906.

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Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1906.

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# American Society of Civil Engineers.

## OFFICERS FOR 1906.

*President*, FREDERIC P. STEARNS.

*Vice-Presidents.*

*Term expires January, 1907:*
M. L. HOLMAN,
E. KUICHLING.

*Term expires January, 1908:*
ONWARD BATES,
BERNARD R. GREEN.

*Secretary*, CHARLES WARREN HUNT.

*Treasurer*, JOSEPH M. KNAP.

*Directors.*

| *Term expires January, 1907:* | *Term expires January, 1908:* | *Term expires January, 1909.* |
|---|---|---|
| CHARLES S. GOWEN, | AUSTIN L. BOWMAN, | GEORGE GIBBS, |
| NELSON P. LEWIS, | MORRIS R. SHERRERD, | J. WALDO SMITH, |
| JOHN W. ELLIS, | HEZEKIAH BISSELL, | EMIL SWENSSON. |
| GEORGE S. WEBSTER, | EDWIN A. FISHER, | JAMES M. JOHNSON, |
| RALPH MODJESKI, | WILLIAM B. LANDRETH, | WYNKOOP KIERSTED, |
| CHARLES D. MARX. | GEORGE S. PIERSON. | WILLIAM B. STOREY, JR. |

*Assistant Secretary*, T. J. McMINN.

## Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

| *On Finance:* | *On Publications:* | *On Library:* |
|---|---|---|
| EMIL KUICHLING, | MORRIS R. SHERRERD, | NELSON P. LEWIS, |
| CHARLES S. GOWEN, | J. WALDO SMITH, | AUSTIN L. BOWMAN, |
| GEORGE GIBBS, | ONWARD BATES, | RALPH MODJESKI, |
| M. L. HOLMAN, | BERNARD R. GREEN, | HEZEKIAH BISSELL, |
| GEORGE S. PIERSON. | GEORGE S. WEBSTER. | CHARLES WARREN HUNT. |

## Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON RAIL SECTIONS:—Joseph T. Richards, C. W. Buchholz, E. C. Carter, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

ON CONCRETE AND REINFORCED CONCRETE:—C. C. Schneider, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, J. W. Schaub, Emil Swensson, A. N. Talbot, J. R. Worcester.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER: - - - - 533 Columbus.
CABLE ADDRESS: - - - - "Ceas, New York."

Vol. XXXII. JANUARY, 1906. No. 1.

# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## SOCIETY AFFAIRS.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

**January 3d, 1906.**—The meeting was called to order at 8.35 P. M.,; President C. C. Schneider in the chair; Chas. Warren Hunt, Secretary; and present, also, 84 members and 22 guests.

The minutes of the meetings of December 6th and 20th, 1905, were approved as printed in the *Proceedings* for December, 1905.

A paper by Albert J. Himes, M. Am. Soc. C. E., entitled "The Position of the Constructing Engineer, and his Duties in Relation to Inspection and the Enforcement of Contracts," was presented by the author. Written communications from Messrs. James Smith Haring, W. D. Lovell, Benjamin Thompson, S. Bent Russell and

Willard Beahan were presented by the Secretary, and the subject was discussed verbally by Messrs. W. A. Aiken, G. S. Bixby, Augustus Smith and the author.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Thomas David Allin, Pasadena, Cal.
James Leland Crider, Mt. Vernon, N. Y.
William Herbert Cushman, Huntingdon, Pa.
Thomas Gregory Dabney, Clarksdale, Miss.
Edward John Duffies, Harbor Beach, Mich.
Chester Shepard Freeland, San Francisco, Cal.
Edward Payson Lupfer, Buffalo, N. Y.
William Vaughan Polleys, Providence, R. I.
Victor da Silva Freire, Sao Paulo, Brazil.
Herman Winslow Spooner, Gloucester, Mass.

As Associate Members.

Edward Maguire Adams, Fort Leavenworth, Kans.
Thomas K Bell, Philadelphia, Pa.
Paul Alexander Blackwell, Canonsburg, Pa.
Harry Westbrook DeGraff, Fonda, N. Y.
Osborne Joel Dempster, Albany, N. Y.
Lorenzo Carlisle Dilks, New York City.
Elmer Dwight Harshbarger, Aspinwall, Pa.
Frank Edward Hermanns, New York City.
Walter Burditt Leane, Cape Colony, South Africa.
Alfred Emanuel Lindau, St. Louis, Mo.
Alexander Majors Munn, Nebraska City, Nebr.
John Peterson, New York City.
Arthur Monroe Shaw, Dixon, Ill.
Edward Clayton Sherman, Boston, Mass.
Charles Bailey Smith, Boise, Idaho.
Raymond French Stoddard, Milford, Conn.
Samuel Forsythe Thomson, New York City.

As Associates.

John Moffatt Bruce, New York City.
William Roberts Conard, Burlington, N. J.

The Secretary announced the transfer of the following candidates, by the Board of Direction, on January 2d, 1906:

FROM ASSOCIATE MEMBER TO MEMBER.

WILLIAM GEORGE BRENNEKE, St. Louis, Mo.
EDWARD BAYRD FAY, St. Louis, Mo.

The election of the following candidates, by the Board of Direction, on January 2d, 1906:

AS JUNIORS.

DUFF ANDREW ABRAMS, Champaign, Ill.
ARTHUR BONIFACE, New York City.
ARTHUR ROBERT BROWN, Bas Obispo, Canal Zone, Panama.
HOWARD FOSS ESTEN, Pawtucket, R. I.
WALTER GOTTLIEB FEDERLEIN, New York City.
JAMES STANLEY FRAZER, Mt. Vernon, N. Y.
RAY PALMER HOVEY, Providence, R. I.
CHARLES HAMILTON LEE, Los Angeles, Cal.
HENRY SCHELL NICHOL, New York City.
ALFRED MOORE O'NEAL, JR., New York City.
DAVID ELLIOTT PENDLETON, Greenville, Miss.
WILLIAM JENNER POWELL, Empire, Canal Zone, Panama.
CHARLES HINKLEY VAN KIRK, Chicago, Ill.
ALFRED MARSHALL WYMAN, East Orange, N. J.

The Secretary announced the following deaths:

ANTHONY HOUGHTALING BLAISDELL, elected Member, March 3d, 1880; died September 9th, 1905.

JAMES MACNAUGHTON, elected Member, May 5th, 1880; died December 29th, 1905.

Adjourned.

**January 17th, 1906.**—The minutes of this, the Annual Meeting, will be printed in the *Proceedings* for February, 1906.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, February 7th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "Test of a Three-Stage, Direct-Connected Centrifugal Pumping Unit," by Philip E. Harroun, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for December, 1905.

**Wednesday, February 21st, 1906.**—8.30 P. M.—At this meeting a paper, entitled "The Economical Design of Reinforced Concrete Floor Systems for Fire-Resisting Structures," by John S. Sewell, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for December, 1905.

**Wednesday, March 7th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Theory of Continuous Columns," by Ernst F. Jonson, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper is published in this number of *Proceedings*.

**Wednesday March 21st, 1906.**—8.30 P. M.—At this meeting a paper, entitled "New Facts about Eye-Bars," by Theodore Cooper, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

### PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 410 Penn Avenue, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner, Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten- Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesborough, England.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

# ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31ST, 1905.

PRESENTED AT THE ANNUAL MEETING, JANUARY 17TH, 1906.

The Board of Direction, in compliance with the Constitution of the Society, presents its report for the year ending December 31st, 1905.

## MEMBERSHIP.

The changes in membership are shown in the following table:

| GRADE. | JAN. 1ST, 1905. | | | JAN. 1ST, 1906. | | | LOSSES. | | | | ADDITIONS. | | TOTALS. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Resident. | Non-Resident. | Total. | Resident. | Non-Resident. | Total. | Transfer. | Resignation. | Dropped. | Death. | Transfer. | Election. | Loss. | Gain. |
| Honorary Members | 1 | 8 | 9 | 1 | 11 | 12 | ... | ... | ... | ... | 2 | 1 | .... | 3 |
| Corresponding Members | .... | 2 | 2 | .... | 2 | 2 | ... | ... | ... | ... | .... | .... | .... | .... |
| Members | 376 | 1 419 | 1 795 | 420 | 1 532 | 1 952 | 2 | 3 | 1 | 24 | *68 | 119 | 30 | 187 |
| Associate Members | 240 | 663 | 903 | 285 | 736 | 1 021 | 64 | 3 | 4 | 8 | †44 | ‡153 | 79 | 197 |
| Associates | 51 | 76 | 127 | 52 | 79 | 131 | 2 | 4 | 1 | 1 | .... | 12 | 8 | 12 |
| Juniors | 116 | 224 | 340 | 119 | 277 | 396 | 46 | 1 | 2 | 3 | .... | 108 | 52 | 108 |
| Fellows | 9 | 18 | 27 | 9 | 16 | 25 | ... | ... | ... | 2 | .... | .... | 2 | .... |
| Total | 793 | 2 410 | 3 203 | 886 | 2 653 | 3 539 | 114 | 11 | 8 | 38 | 114 | 393 | 171 | 507 |

* 64 Associate Members, 1 Associate and 3 Juniors.
† 1 Associate and 43 Juniors.
‡ 2 Reinstatements.

It will be seen that the net increase during the year has been 336, which is 57 greater than ever before. The yearly net gains in total membership, beginning with 1899, are given below. Prior to that year the yearly increase reached 100 only four times, no two of which were consecutive.

| Year. | Net increase. |
|---|---|
| 1899 | 103 |
| 1900 | 138 |
| 1901 | 190 |
| 1902 | 185 |
| 1903 | 212 |
| 1904 | 279 |
| 1905 | 336 |
| Total net increase in seven years | 1 443 |
| Average net yearly increase | 206 |

For comparison, the average net increase previous to 1899 is given below.

| | | | | | |
|---|---|---|---|---|---|
| Average net yearly increase | | | | 1870-78..... | 48.1 |
| " | " | " | " | 1879-88..... | 61.1 |
| " | " | " | " | 1889-98..... | 89.3 |

The total number of applications received during the year was 549.

The losses by death reported during the year number 38. They are as follows:

Members: Julius Baier, Burr Bassell, Anthony Houghtaling Blaisdell, Robert Cartwright, George William Catt, Casimir Constable, Frederick de Funiak, George William Frank, Edward Sherman Gould, David Maxson Greene, Frank March Haines, Richard Somers Hayes, George Anthony Lederle, Gabriel Leverich, Thomas John Long, James MacNaughton, George Anson Marr, Edmund Trowbridge Dana Myers, William Beswick Myers-Beswick, John Talcott Norton, Sutherland Mallet Prevost, William Marshall Rees, Archer Cochran Stites, Nathan Hollis Whitten.

Associate Members: Justin Burns, Frank Lewis Fales, Van Dusen Hite-Smith, Louis Ralph Lavalle, Henry Brigham Looker, William Smith Morison, Macy Stanton Pope, George Draper Stratton.

Associate: Cassius Howard Lindenberger.

Juniors: George Wallace Enos, Shukichi Fujino, George Clifton Woollard.

Fellows: Thomas Cooper Coleman, George Clarke Walker.

## LIBRARY.

The accessions to the Library during the year are shown in the following table:

ACCESSIONS DURING THE YEAR 1905.

| | Bound Volumes. | Unbound Volumes. | Specifications. | Maps, Photographs and Drawings. | Total. |
|---|---|---|---|---|---|
| Donations— | | | | | |
| In answer to special requests ..... | 289 | 463 | ... | 147 | 899 |
| From publishers.... | 61 | 9 | ... | ... | 70 |
| In regular course.... | 504 | 1 292 | 267 | 116 | 2 179 |
| By purchase..... | 142 | 27 | ... | ... | 169 |
| Totals..... | 996 | 1 791 | 267 | 263 | 3 317 |

In addition to the above, there have been received 781 duplicates, and 15 separate numbers to complete files of periodicals, neither of which can appear as accessions.

The total number of titles in the Library is 21 083.

The Library now contains:

| | |
|---|---|
| Bound volumes | 14 458 |
| Unbound volumes | 28 912 |
| Specifications | 6 269 |
| Maps, photographs and drawings | 3 730 |
| Total | 53 369 |

During the year, 359 volumes have been bound, and 19 bound volumes which are duplicates were received and have replaced previously unbound volumes.

The following amounts have been expended upon the Library during the year:

| | |
|---|---|
| Purchase of books, 196 volumes | $549.84 |
| Express charges, etc | 11.72 |
| Binding 359 volumes | 424.05 |
| Fixtures, supplies and sundries | 94.37 |
| Total | $1 079.98 |

The value of the accessions to the Library during the year is as follows, each accession having been valued separately, as received:

| | |
|---|---|
| 3 149 Donations and exchanges (estimated value) | $2 295.53 |
| 169 Volumes purchased (cost) | 442.52 |
| Binding 359 volumes | 424.05 |
| Total | $3 162.10 |

During the year 2 869 persons have used the Reading Room and Library.

Searches have been made for 54 persons, covering 825 separate references. These searches, the expense of which is trifling, seem to be of great convenience and value to those who ask for them.

During the year, as heretofore, every effort has been made to secure by gift, if possible, and, if not, by purchase, every engineering work published which should be on our shelves.

From time to time members have suggested the advisability of making the Library a circulating one, and this has been frequently considered by the Board. The difficulties in the way of such a project, however, including the prohibitive cost of securing at least

one or more duplicates of all books of reference, seem to be insurmountable.

## PUBLICATIONS.

During the year the usual ten numbers of *Proceedings* and two volumes of *Transactions* have appeared.

In the *Proceedings,* the list of references to current engineering literature has covered 113 pages, containing 5 430 classified references to 83 periodicals. Last year only 71 periodicals were reviewed.

The stock of the various publications of the Society, kept on hand for the convenience of members and others, now amounts to 136 416 copies, the cost of which to the Society, for paper and press-work only, has been $18 574.86.

During the year, 11 402 volumes of the Society publications have been bound, for members and others, in the standard half-morocco or cloth bindings.

The extra publications during the year have been six volumes of *Transactions* containing the papers and discussions of the International Engineering Congress. Details as to this publication are given under another heading.

SUMMARY OF REGULAR PUBLICATIONS FOR 1905.

| | Issued. | Edition. | Total Pages. | Plates. | Cuts. |
|---|---|---|---|---|---|
| *Transactions* (Volumes)*.... | 2 | 3 725 | 1 034 | 127 | 160 |
| *Proceedings* (Monthly Numbers)..... | 10 | 3 375 | 1 271 | 104 | 107 |
| Constitution and List of Members..... | 1 | 4 200 | 248 | ... | 1 |
| Total..... | 13 | .... | 2 553 | 231 | 268 |

| | |
|---|---|
| The cost of regular publications has been: | |
| For Paper, Printing, Binding, etc., *Transactions* and *Proceedings* ..... | $11 375.45 |
| For Plates and Cuts..... | 1 733.78 |
| For Boxes, Mailing Lists, Copyright and Sundry Expenses ..... | 375.97 |
| For 5 940 copies of Memoirs and Papers..... | 741.03 |
| For List of Members..... | 1 147.90 |
| Total..... | $15 374.13 |
| Deduct amount received from sale of publications..... | 2 501.98 |
| Net cost of Regular Publications for 1905..... | $12 872.15 |

* Includes Indexes and Tables of Contents.

## PUBLICATIONS OF THE INTERNATIONAL ENGINEERING CONGRESS.

The last report of the Board contained an outline of the work of the International Engineering Congress from its inception in September, 1903, to January 1st, 1905. At that date the Board reported that the work of preparing the discussions was in progress, and that it was hoped to have the whole Congress Publication ready for issue before July 1st, 1905. This expectation was realized. The discussions were collated, put in type, forwarded to the Author of each paper, and, with his closure, published with the paper. All papers and discussions were grouped by subjects. The result is embraced in six volumes, issued, for convenience, as Parts A, B, C, D, E and F of Volume LIV of *Transactions,* and your Board believes that the quality and extent of this publication fully justified the labor and expense which was assumed by the Society.

These extra volumes were furnished without cost to all members, and were also furnished to 335 subscribers, 192 of whom paid $5, and 143, $10. A number of sets have also been sold at $5 per volume. Persons who joined the Society after January 1st, 1905, may secure these volumes at a special price of $2.50 per volume.

SUMMARY OF PUBLICATIONS OF THE INTERNATIONAL ENGINEERING CONGRESS, 1905, *Transactions,* Volume LIV, Parts A, B, C, D, E and F.

| | | |
|---|---|---|
| Number of Volumes | 6 | |
| Edition | 4 000 | |
| Total Pages | 3 398 | |
| Number of Plates | 248 | |
| " " Cuts | 441 | |
| " " Subjects treated | 36 | |
| " " Papers | 96 | |
| " " Discussions | 302 | |
| Separate Papers Printed | 19 675 | |
| The total cost of the Congress has been | | $38 462.80 |
| Amount expended in 1904 for this account | | 13 579.27 |
| Amount expended during 1905 | | $24 883.53 |
| There has been received from subscriptions and sales of publications of the Congress | | $4 949.05 |

Owing to these extra publications, the work of the staff of the Society was materially increased during the year. An idea may be

conveyed by the statement that of the publications alone more than 80 000 separate pieces were handled.

## LOCAL ASSOCIATIONS OF MEMBERS.

The formation of Local Associations of Members of the Society in the larger cities of the country has received much attention during the past year. The Board prepared a report on the subject which was presented to the Society at the Annual Convention at Cleveland, where the subject was fully discussed.

Local Associations of Members of the Society have been successfully organized at Kansas City, Mo., San Francisco, Cal., and Memphis, Tenn., and much interest has been manifested in other centers.

## MEETINGS.

During the year, 24 meetings have been held, as follows: Annual Meeting, 2; at the Annual Convention, 4; regular semi-monthly meetings, 18.

At these meetings there were presented 21 formal papers, two of which were illustrated with lantern slides, and two illustrated lectures.

The Thirty-seventh Annual Convention was held at Cleveland, Ohio, at which the registered attendance numbered 320 members and 255 guests.

## MEDALS AND PRIZES.

For the year ending with the month of July, 1904, Prizes were awarded as follows:

The Norman Medal to Emile Low, M. Am. Soc. C. E., for his paper entitled "The Breakwater at Buffalo, N. Y."

The Thomas Fitch Rowland Prize to George Cecil Kenyon, Assoc. M. Am. Soc. C. E. (now M. Am. Soc. C. E.), for his paper entitled "Dock Improvements at Liverpool."

The Collingwood Prize for Juniors to Herbert J. Wild, Jun. Am. Soc. C. E. (now Assoc. M. Am. Soc. C. E.), for his paper entitled "The Substructure of Marsh River Bridge."

## SOCIETY HOUSE.

In its last report the Board informed the membership of the purchase of the 25-ft. lot adjoining the Society House, and stated that general plans were being prepared with the expectation that the work of enlargement would go on during 1905.

The Board now reports that plans for the enlargement were prepared by Messrs. Eidlitz and McKenzie early in the year. Competitive bids were secured, and on May 2d, 1905, a contract was signed with William L. Crow amounting to $52 497.

Owing to the difficulty of getting steel and to some minor labor troubles, the work is not completed, but it is expected at this writing that the building will be far enough advanced to enable the Annual Meeting to be held in it.

In a general way, the addition provides an enlargement of 50% in every department of the Society's work. The Lounging Room and Auditorium are each increased in length 25 ft. An additional Reading Room is provided on the second floor, and the capacity of the offices on the third floor, as well as the Stack Room on the fourth floor, has been materially increased.

The rooms which were used in the old building as offices of the Secretary have been added to the entrance hallway, forming a new Reception Hall, and the entrance to the Lounging Room as well as the toilet facilities have been enlarged.

A stairway leading from the Lounging Room to the Auditorium has been provided, which it is believed will add much to the facilities of the building, and to the comfort of those in attendance at meetings.

The building operations have been in the hands of a Committee consisting of Messrs. Noble, Deyo, N. P. Lewis and Hunt. As soon as a final settlement is made, the report of this Committee will be published in *Proceedings* for the information of members.

## FINANCES.

The attention of Members is invited to the Secretary's statement of receipts and disbursements, and to the general balance sheet which accompanies it, in which the very satisfactory financial condition of the Society appears.

In a circular issued by the Board of Direction dated May 25th, 1895, when the building of a Society House was first contemplated, the available assets of the Society were stated to be as follows:

| | |
|---|---|
| "The House 127 East 23d St. (estimate).... | $60 000 |
| "Securities in Safe Deposit (par value).... | 16 000 |
| "Cash awaiting permanent investment..... | 4 500 |
| "Total..... | $80 500 |
| "Mortgage on 127 E. 23d St..... | 16 000 |
| "Amount Available..... | $64 500" |

When the enlargement of the Society House is finished and paid for, a similar statement will be about as follows:

| | |
|---|---|
| Lot (75 by 112) 218-222 W. 57th St. (estimate) | $270 000.00 |
| House (1897) Cost | 103 597.83 |
| Addition (1905-06) (estimate) | 60 000.00 |
| Total | $433 597.83 |
| Mortgage and Loan | 190 000.00 |
| Total value of real property, above debt. | $243 597.83 |

It should be noted that the above statement relates only to the real property of the Society, and does not show the increased value of the Library nor the amount expended for furniture, etc.

In closing this report the Board desires to call attention to the generous donation of Thomas Fitch Rowland, Hon. M. Am. Soc. C. E. Resolutions of thanks have already been adopted by the Board and by the Society, but the Board wishes to emphasize in this report its high appreciation of this timely contribution to the funds of the Society.

The reports of the Secretary and Treasurer are appended.

By order of the Board of Direction.

CHAS. WARREN HUNT,
*Secretary.*

NEW YORK, JANUARY 2D, 1906.

## REPORT OF THE TREASURER.

In compliance with the provisions of the Constitution, the Treasurer presents the following report for the year ending December 31st, 1905:

| | | | |
|---|---|---|---|
| Balance on hand December 31st, 1904 | | | $49 927.49 |
| Receipts from current sources, January 1st to December 31st, 1905 | | | 81 742.14 |
| Extraordinary Receipts on account of: | | | |
| Donation | $5 000.00 | | |
| International Engineering Congress | 2 333.90 | | |
| St. Louis Exhibit and Headquarters | 195.89 | | |
| Entertainment of British Engineers | 80.00 | | |
| Additional Loan | 3 000.00 | | |
| | | | 10 609.79 |
| Payment of Audited Vouchers for Current Business, January 1st to December 31st, 1905 | | $67 296.94 | |
| Extraordinary Expenses on account of: | | | |
| Building | $36 919.80 | | |
| International Engineering Congress | 24 932.93 | | |
| Entertainment of British Engineers | 172.50 | | |
| | | 62 025.23 | |
| Balance on hand December 31st, 1905: | | | |
| In Union Trust Company. | $5 395.51 | | |
| In Garfield National Bank. | 6 061.74 | | |
| In hands of the Treasurer. | 1 500.00 | 12 975.25 | |
| | | $142 279.42 | $142 279.42 |

Respectfully submitted,

JOS. M. KNAP,

*Treasurer, Am. Soc. C. E.*

NEW YORK, JANUARY 2D, 1906.

## REPORT OF THE SECRETARY, FOR THE

To the Board of Direction of the

Gentlemen:—I have the honor to present a statement of Re-
December 31st, 1905. I also append a general balance sheet show-
New York, January 2d, 1905.

### Receipts.

| | | |
|---|---|---|
| Balance on hand December 31st, 1904, in Bank, Trust Company and in hands of Treasurer..... | | $49 927.49 |
| Entrance Fees..... | $9 665.00 | |
| Current Dues..... | 37 642.58 | |
| Past Dues..... | 1 519.71 | |
| Advance Dues..... | 17 595.11 | |
| Certificates of Membership..... | 352.75 | |
| Badges ..... | 2 014.50 | |
| Sales of Publications..... | 2 501.98 | |
| Interest ..... | 987.07 | |
| Library ..... | 272.85 | |
| Convention ..... | 507.00 | |
| Annual Meeting..... | 894.00 | |
| Binding ..... | 7 676.80 | |
| Miscellaneous ..... | 112.79 | |
| Donation ..... | 5 000.00 | |
| International Engineering Congress..... | 2 333.90 | |
| Louisiana Purchase Exposition..... | 195.89 | |
| Entertainment of British Engineers..... | 80.00 | |
| Loan and Mortgage..... | 3 000.00 | |
| | | $92 351.93 |
| | | $142 279.42 |

YEAR ENDING DECEMBER 31ST, 1905.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

ceipts and Disbursements for the fiscal year of the Society, ending
ing the condition of the affairs of the Society.

Respectfully submitted,

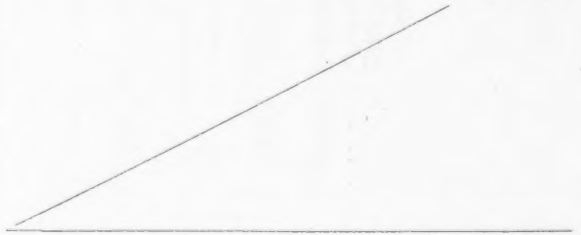
CHAS. WARREN HUNT,
*Secretary.*

DISBURSEMENTS.

| | | |
|---|---|---|
| Salaries of Officers | $8 500.00 | |
| Clerical Help | 12 323.35 | |
| Caretaking | 1 771.94 | |
| Publications | 15 374.13 | |
| Postage | 3 763.33 | |
| General Printing and Stationery | 2 324.51 | |
| Badges | 1 636.90 | |
| Certificates of Membership | 222.70 | |
| Binding | 6 542.70 | |
| Library | 1 079.98 | |
| Maintenance of House | 285.80 | |
| Heat, Light and Water | 1 116.50 | |
| Furniture | 201.50 | |
| Annual Meeting | 1 528.25 | |
| Convention | 1 131.51 | |
| Prizes | 179.85 | |
| Interest and Insurance | 8 676.98 | |
| Petty Expenses | 185.49 | |
| Entertainment of British Engineers | 172.50 | |
| Building | 36 888.55 | |
| Louisiana Purchase Exposition | 31.25 | |
| Refunds | 10.35 | |
| Current Business | 441.17 | |
| International Engineering Congress | 24 932.93 | |
| | | $129 322.17 |
| Balance on hand December 31st, 1905: | | |
| In Union Trust Company | $5 395.51 | |
| In Garfield National Bank | 6 061.74 | |
| In hands of Treasurer | 1 500.00 | |
| | | $12 957.25 |
| | | $142 279.42 |

| ASSETS. | | |
|---|---|---|
| Three Lots (estimated value) | | $270 000.00 |
| Society Building (cost) | | 140 486.38 |
| Furniture (cost) | | 16 534.94 |
| Publications on hand (inventoried cost, value) | | 18 574.86 |
| Library: | | |
| Cash expended for Books, etc. | $10 400.03 | |
| Donations, estimated value | 47 055.59 | |
| | | 57 455.62 |
| Due from Members | $4 265.29 | |
| " " Non-Members | 415.43 | |
| | | 4 680.72 |
| Cash | | 12 957.25 |
| | | $520.689.77 |

| LIABILITIES. | | |
|---|---|---|
| Dues for 1906, paid in advance | | $17 595.11 |
| Mortgage Debt and Loan | | 178 000.00 |
| *Funds invested in Society House, Lots and Library. | $26 730.78 | |
| Surplus | 298 363.88 | |
| | | 325 094.66 |
| | | $520.689.77 |



| *These Funds have been derived from the following sources: | |
|---|---|
| Norman Medal Fund | $1 000.00 |
| Rowland Prize Fund | 1 222.50 |
| Collingwood Prize Fund | 1 000.00 |
| McCrea Swift Fund | 1 000.00 |
| Herbert Stewart Library Fund | 1 949.00 |
| Fellowship Fund | 13 038.28 |
| Compounding Dues Fund | 7 530.00 |
| | $26 730.78 |

The Norman Medal, Rowland Prize and Collingwood Prize Funds no longer exist as such, the obligations under them having been assumed by the Society, with the consent of the donors.

NEW YORK, 12TH JANUARY, 1906.—We have examined the books and accounts of the American Society of Civil Engineers, and certify that the foregoing Balance is in accordance therewith, as of 31st December, 1905; and, in our opinion, correctly states the condition of the Society's affairs as shewn by the books at that date.

MENZIES, FAWCETT, TOD & Co.,
*Chartered Accountants.*

# ACCESSIONS TO THE LIBRARY.

From December 11th, 1905, to January 6th, 1906.

## DONATIONS.*

### MODERN TURBINE PRACTICE AND WATER POWER PLANTS.

By John Wolf Thurso. Cloth, 9 x 6 in., illus., 22 + 244 pp. New York, D. Van Nostrand Company, 1905. $2 net.

The preface states that the object of this book is to give such information in regard to modern turbines and their proper installation as is necessary to the hydraulic engineer in designing a water-power plant, and no attempt has been made to treat the design of turbines. In the first part the writer has intended to show the deficiencies of the present American turbine practice and to point out the direction in which improvement is to be sought. On account of the growing importance of the steam turbine and its close relation to the hydraulic turbine, a chapter has been included on this subject. In the second part will be found information and data relative to turbine plants. Following the preface are a few pages of terms and symbols used in hydraulic-power engineering. Contents: Part I.—Modern Turbine Practice: Turbine Practice in Europe; Turbine Practice in America; Classification of Turbines; Steam Turbines; Modern Turbine Types and Their Construction; Accessories to Turbines; Governors and Speed Regulators. Part II.—Water Power Plants: Water-Conductors; British and Metric Measures and Values. There is an index of six pages. At the end of the book is Mr. Allan V. Garratt's paper on speed regulation of turbines, reprinted from the *Transactions* of the American Institute of Electrical Engineers.

### MACHINE TOOLS.

For Planing, Shaping, Slotting, Drilling, Boring, Milling, Wheel Cutting, Their Design and Construction. By Thomas Shaw. Cloth, 9 x 6 in., illus., 7 + 676 + 8 pp. Manchester, England, The Scientific Publishing Company. 15 shillings.

In this work the author aims to review the construction of the different types of machine tools in which, generally speaking, the work is either held stationary or moves in straight lines, as distinguished from those to which a direct rotary motion is given. He has endeavored to present, from actual practice, a number of examples of each type of machine, showing the different mechanisms with their respective constructional surroundings, and, in some cases, the complete arrangement of details. Besides the chapters dealing with the construction of the machines, there has been added a chapter of useful items and miscellaneous information collected from the author's personal experience and other sources. The contents are: Planing Machines; Shaping and Slotting Machines; Vertical Drilling Machines; Radial Drilling Machines; Horizontal Boring and Drilling Machines; Multiple-Spindle Drilling Machines; Milling Machines; Wheel-Cutting Machines; Items of Interest, and Appendix. There is an index of seven pages.

### CONTRIBUTION À L'ÉTUDE DE LA FRAGILITÉ DANS LES FERS ET LES ACIERS.

Mémoires Originaux et Réimpressions; Publication faite avec le Concours des Six Grandes Compagnies de Chemins de Fer Français. Société D'Encouragement pour l'Industrie Nationale. Paper, 10 x 9, illus., 16 + 482 pp. Paris, Siège de la Société, 1904. $6.

This work comprises original papers and reprints on the brittleness of steel, with an introduction by H. Le Chatelier. Some of the contents are: Résistance au Choc et Fragilité du Fer, et Mesure de la Fragilité de l'Acier et du Fer, par M. Considère; Influence de la Température sur les Propriétés Mécaniques des Métaux, par M. André Le Chatelier; Fragilité après Ecrouissage à Froid et Fissilité, par M. Considère; Fragilité des Aciers, par M. Godron; Aciers Propres à la Construction des Machines, par M. Auscher; Nouvelle Méthode d'Essai des Métaux, par M. Ch. Frémont; Influence du Temps et de la Température sur les Propriétés Mécaniques et les Essais des Métaux, par M. André Le Chatelier; Etude Experimental des Causes de la Fragilité de l'Acier,

*Unless otherwise specified, books in this list have been donated by the publishers.

ACCOMPANYING THE REPORT OF THE SECRETARY.

par M. Ch. Frémont; Sur le Pliage des Barrettes Entaillées, par MM. Ch. Frémont et F. Osmond; Flexion par Choc sur Barreaux Entaillés, par M. J. Barba, et par M. G. Charpy; Essai des Métaux par Pliage de Barrettes Entaillées, par M. Ch. Frémont; Essai de Fragilité au Choc sur Barreaux Entaillés, par M. H. Le Chatelier; Note sur le Rôle des Essais dans le Controle du Material Roulant de Chemin de Fer, et L'Essai au Choc des Métaux dans la Construction du Matérial Roulant de Chemin de Fer, par M. F. Vanderheym. The book has a table of contents, but contains no index.

**INDEX TO ENGINEERING NEWS FOR THE YEARS 1900 TO 1904 INCLUSIVE.**

Compiled by Mary E. Miller. Cloth, 9 x 6 in., 290 pp. New York, Engineering News Publishing Company, 1905. $2.

The introduction states that the present publication, indexing the ten volumes of *Engineering News* issued from January 1st, 1900, to January 1st, 1905, is the third such general index to this journal which has been issued. The first covered the sixteen years from the foundation of the journal in 1874 to the end of 1890. The second, a much larger and more systematically compiled volume, covered the years from 1890 to 1899, inclusive; and the present, as just stated, covers the matter published in the five years following. As a slight indication of the growth of the engineering profession and the corresponding growth of *Engineering News*, it may be here noted that the first general index, covering the sixteen years preceding 1890, was a volume of 118 pages; the second book, covering the decade preceding 1900, contained 324 pages, and the present volume, covering only half a decade, contains 291 pages. In part, however, the increase in size is due to more careful and complete indexing. The present volume is designed to be a labor-saving aid in the use of *Engineering News*. The introduction also contains suggestions on how to use the index. The author index at the end of this book is a new feature, not contained in the other volumes.

**A POCKET BOOK OF MECHANICAL ENGINEERING;**

Tables, Data, Formulas, Theory and Examples for Engineers and Students. By Charles M. Sames. Leather, 6 x 4 in., 8 + 168 pp. Jersey City, N. J., Charles M. Sames, 1905. $1.50.

This book is the result of the writer's endeavor to compact the greater part of the reference information, usually required by mechanical engineers and students, into a volume, the dimensions of which permit of its being carried in the pocket without inconvenience. The author states that in its preparation he has consulted standard treatises and reference books, the transactions of engineering societies and his own memoranda, which extend over a period of fifteen years. A large amount of valuable and timely matter has been obtained from the columns of technical periodicals and also from the catalogues which manufacturers have courteously placed at his disposition. The contents are: Mathematics; Chemical Data; Materials; The Strength of Materials, Structures and Machine Parts; Energy and the Transmission of Power; Heat and the Steam Engine; Hydraulics and Hydraulic Machinery; Shop Data; Electrotechnics; Addenda. There is an index of six pages.

**EARTHWORK TABLES.**

By R. S. Henderson. Paper, 12 x 9 in., 32 pp. New York, The Engineering News Publishing Company, 1905. $1.

Part I gives Cubic Yards per 100 Feet for Level Sections; Bases up to 50 Feet varying by 1 Foot; Heights up to 25 Feet varying by 0.1 Foot; Heights, 25 Feet to 50 Feet, varying by 0.5 Foot; Heights, 50 Feet to 100 Feet, varying by 1 Foot; Quantities given direct for Slope of 1½ to 1; Quantities for 10 other Slopes given by one Addition or Subtraction; Results to the nearest Yard; To which is added a Graphical Method of Estimating Quantities from a Profile. Part II gives the Volume, in Cubic Yards, of Prismoids, 100 Feet Long, by the Average End-Area Method; sums of End Areas up to 10 000 Square Feet, varying by tenths; Cubic Yards per 100 Feet to the nearest tenth; Sums of End Areas up to 1 000 Square Feet, varying by hundredths; Cubic Yards per 100 Feet, to the nearest hundredth.

**HYDROGRAPHIC SURVEYING;**

Methods, Tables and Forms of Notes. By Samuel H. Lea, M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 172 pp. New York, The

Engineering News Publishing Company, 1905. $2 net (donated by the author).

The author states in the preface that this work is intended to be useful to engineering students and the younger members of the profession, as well as to those engineers of larger experience, who are not thoroughly familiar with the minor details of Hydrographic Surveying, much of the matter contained in the manual being elementary and the hydraulic formulas being stated as nearly as practicable in their simplest forms. It is the author's purpose to explain such practical features of hydrographic surveying as are likely to be encountered in actual practice and are at present to be learned only by actual field experience. It is stated that much of the information was acquired by the author in the course of his professional work, consequently, it has the merit of practicality. He has endeavored to limit the scope to such ordinary methods of hydrographic surveying as are likely to occur, and desires to embody within this little book a concise explanation of modern methods. There is no index.

**MODERN MACHINE SHOP;**

Construction, Equipment and Management. By Oscar E. Perrigo. Cloth, 10 x 7 in., illus., 343 pp. New York, The Norman W. Henley Publishing Company, 1906. $5.

The aim of the author has been to produce a work suitable for the practical and every-day use of the architects who design, the manufacturers who build, the engineers who plan and equip, the superintendents who organize and direct, and for every stockholder, officer and workman of the modern machine shop and manufacturing plant. Part First is devoted to the *Construction*, describing and illustrating buildings of approved form and arrangement; Part Second to *Equipment* with modern tools, machines and appliances; and Part Third discusses the question of *Management*, minutely describing and illustrating, it is stated, a plain, concise, accurate and common-sense system of management and of time and cost keeping, that may be easily and economically administered and give information necessary for operating the business to financial success. There is an index of nearly sixteen pages.

**PRACTICAL PATTERN-MAKING.**

By F. W. Barrows. Cloth, 7 x 5 in., illus., 326 pp. New York, The Norman W. Henley Publishing Company, 1906. $2.

It is stated that the aim of this book is to be a thoroughly practical work. It is written by a pattern-maker with thirty years' experience, and contains information on pattern-making and pattern-makers in general, and a detailed description of the necessary materials, hand and machine tools, with special chapters on the lathe, the band-saw and the circular saw, with examples of work which may be done on these machines. A complete section of illustrated examples of pattern-work in wood, with many pages of metal pattern-work, gating and plate work, both vibrator and stripping plates, are shown. Some mathematics for the pattern shop are given, and finally the cost, marking and record of patterns is explained and illustrated. There is an index of fourteen pages.

Gifts have also been received from the following:

Allen, W. F. 1 vol.
Am. Soc. for Testing Materials. 1 vol.
Am. Soc. of Heating and Ventilating Engrs. 1 vol.
Am. Water Works Assoc. 1 vol.
Atlantic Coast Line R. R. Co. 2 pam.
Bixby, G. S. 2 pam.
Brit. Fire Prevention Committee. 1 pam.
Cal. Academy of Sci. 2 pam., 1 vol.
Chicago, Ill.—Dept. of Public Works. 1 pam.
Chicago Junction Rys. & Union Stock Yards Co. 1 pam.
Colo.—State Agri. Exper. Station. 3 pam.
Cornell Univ. Library. 1 pam.
Endicott, M. T. 1 vol.
Eng. Standards Committee. 1 bound vol.
Florida—Railroad Comm. 3 pam.
Foster-Munger Co. 1 vol.
Great Britain—Patent Office. 3 vol.
Hermany, Charles. 4 vol.
Humphreys, A. C. 1 pam.
Indian Midland Ry. Co., Ltd. 1 pam.
Inst. of Engrs. and Shipbuilders in Scotland. 1 bound vol.
Kenyon, G. C. 1 pam.
Lehigh & Hudson River Ry. Co. 1 pam.
London, Ont.—Board of Water Commrs. 1 pam.
Madras, India—Public Works Dept. 5 vol.
Mahl, William. 2 vol.
Mass. Inst. of Tech. 1 vol.
National Board of Fire Underwriters Committee of Twenty. 1 vol., 2 pam.

National Irrig. Congress. 1 vol.
New South Wales—Govt. Statistician. 2 pam.
New York City—Dept. of Health. 1 pam.
New York—State Library. 1 pam.
New York—State Museum. 1 vol.
Nichols, T. F. 4 vol.
Ockerson, J. A. 1 pam.
Ohio—State Geologist. 1 pam.
Pere Marquette R. R. Co., 4 pam.
Platt, T. C. 7 vols.
Southern Pacific Co. 1 vol.
*Tonindustrie-Zeitung.* 1 bound vol., 2 vol.
U. S. Bureau of the Census. 1 bound vol.
U. S. Corps of Engrs. 23 specif.
U. S. Dept. of Agri. 1 pam.
U. S. Lake Survey Office. 2 pam.
U. S. Naval War Records Office and Library. 4 vols., 5 pam.
Unknown. 1 vol.
Virginia—Dept. of Agri. and Immigration. 1 vol.
Ziino, Sibaldo. 1 pam.

## BY PURCHASE.

**Rapports de Service.** Par E. Dardart et Philippe Dufour. Sténographie. Par Zryd. (Bibliothèque du Conducteur de Travaux Publics.) Paris, H. Dunod et E. Pinat, 1905.

**Législation des Eaux.** Par Louis Courcelle et E. Dardart. (Bibliothèque du Conducteur de Travaux Publics.) Paris, H. Dunod et E. Pinat, 1905.

**Étude sur les Murs de Réservoirs.** Par J. B. Krantz. Paris, Dunod, 1870.

**Base, Contour and Relief Maps.** U. S. Geological Survey. Washington, D. C., 1904.

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## SUMMARY OF ACCESSIONS.

December 11th, 1905, to January 6th, 1906.

| | |
|---|---|
| Donations (including 12 duplicates)..... | 125 |
| By purchase..... | 6 |
| Total ..... | 131 |

## MEMBERSHIP.

### ADDITIONS.

#### MEMBERS.

| | | Date of Membership. |
|---|---|---|
| ALBER, HERMANN. (Wilson & Alber, Cons. Engrs.), 1216 N. 24th St., Birmingham, Ala. | | Dec. 6, 1905 |
| BACON, GEORGE MORGAN. 84 R St., Salt Lake City, Utah. | Assoc. M. | Dec. 3, 1902 |
| | M. | Dec. 5, 1905 |
| BALDWIN, ARCHIBALD STUART. Chf. Engr., I. C. R. R., Chicago, Ill. | | Dec. 6, 1905 |
| BELDEN, HARRY AUSTIN. Care, J. G. White & Co., Inc., Manila, Philippine Islands. | | Oct. 4, 1905 |
| CARPENTER, CHARLES LINCOLN. Asst. Engr., Isthmian Canal Comm., Bas Obispo, Canal Zone, Panama. | | Dec. 6, 1905 |
| CLAPP, WILLIAM BILLINGS. 205 So. Fair Oaks Ave., Pasadena, Cal. | | Dec. 6, 1905 |
| GALLOWAY, JOHN DEBO. Cons. Civ. Engr., Rialto Bldg., San Francisco, Cal. | | Dec. 6, 1905 |
| GOODRICH, ERNEST PAYSON. Cons. Engr.; Chf. Engr., Bush Cos., 100 Broad St., New York City. | Jun. | April 3, 1900 |
| | M. | Nov. 1, 1905 |
| HUMPHREY, HENRY CYPRIAN. Provincial Superv., Lucena, Tayabas Province, Philippine Islands. | Assoc. M. | Sept. 4, 1901 |
| | M. | Oct. 3, 1905 |
| LEFFINGWELL, FRANK DODGE. Res. Engr., Rapid Transit Subway Constr. Co., 350 Fulton St., Brooklyn, N. Y. (Res., 13 Lexington Ave., Montclair, N. J.) | Assoc. M. | Oct. 5, 1898 |
| | M. | Dec. 5, 1905 |
| MCCORMACK, EDGAR WALTER. 110 O'Reilly St., Havana, Cuba. | Assoc. M. | Mar. 6, 1901 |
| | M. | Dec. 5, 1905 |
| NEHER, FRANK. Prin. Asst. Engr., Mo. Pac. Ry., 7th and Poplar Sts., St. Louis, Mo. | | Oct. 4, 1905 |
| NEWTON, ALBERT WILLIAM. 610 Globe-Democrat Bldg., St. Louis, Mo. | | Dec. 6, 1905 |
| PARKS, OREN ELISHA. Civ. Engr. and Surv., 82 North Elm St., Westfield, Mass. | | Dec. 6, 1905 |
| WARNER, FRANK CHARLES. U. S. Asst. Engr., Delaware City, Del. | | Dec. 6, 1905 |
| WOOD, FREDERIC JAMES. Chf. Engr., Boston, Pawtucket & Providence St. Ry. Co.; Cons. Engr., Norfolk & Bristol St. Ry. Co., Foxboro, Mass. | | Dec. 6, 1905 |

#### ASSOCIATE MEMBERS.

| | | |
|---|---|---|
| ADAMS, RAYMOND EDMOND. Civ. Engr., Quarter Master General's Office, 702 Seventeenth St., N. W., Washington, D. C. | Jun. | May 1, 1900 |
| | Assoc. M. | Dec. 6, 1905 |

ASSOCIATE MEMBERS (*Continued*).

| | | Date of Membership. |
|---|---|---|
| ALLEN, EUGENE YORKE. Asst. Res. Engr., Bergen Hill Tunnels, P., N. J. & N. Y. R. R., Weehawken Shaft, P. O. Station No. 1, Hoboken, N. J | | Dec. 6, 1905 |
| BARNES, WALTER ESMOND. 45 Lincoln St., Malden, Mass | Jun. | May 6, 1902 |
| | Assoc. M. | Dec. 6, 1905 |
| BUCK, CON MORRISON, Office Engr., A., T. & S. F. Ry., 1006 Garfield Ave., Topeka, Kans | | Dec. 6, 1905 |
| GRADY, JOHN EDWARD. Engr., Bridge Constr., San. Dist. of Chicago, 716 East 50th St., Chicago, Ill | | Dec. 6, 1905 |
| GRAY, JOHN LATHROP. Engr. and Asst. Supt., Paraffine Works of Tide Water Oil Co., Bayonne, N. J | | Dec. 6, 1905 |
| HILDRETH, JOHN LEWIS, JR. Topographical Draftsman, Bureau of Highways, 4 Court Sq., Brooklyn, N. Y. | | Dec. 6, 1905 |
| MELIUS, LUDLOW LAWRENCE. Glenmont, N. Y. | Jun. | May 2, 1899 |
| | Assoc. M. | Dec. 6, 1905 |
| SEVERSON, OSCAR MELVERN. Div. Engr., B. & S. Ry. Co., 992 Ellicott Sq., Buffalo, N. Y | | Dec. 6, 1905 |
| STOCKTON, JOHN. Asst. Engr., C. W. Leavitt, Jr., 15 Cortlandt St., New York City | | Dec. 6, 1905 |
| TOOKER, FRANK WESTERVELT. With Chas. W. Leavitt, Jr., 15 Cortlandt St., New York City | | Dec. 6, 1905 |
| WIDDICOMBE, ROBERT ALEXANDER. Mgr. and Engr., Steam Fitting Dept., Kroeschell Bros. Co., Chicago, Ill | Jun. | April 2, 1901 |
| | Assoc. M. | Dec. 6, 1905 |
| WILSON, WILLIAM EDWARD. Asst. Prof., Civ. Eng., Univ. of Utah; Civ. and Cons. Engr., 14 Eng. Bldg., Univ. of Utah, Salt Lake City, Utah | Jun. | Jan. 6, 1903 |
| | Assoc. M. | June 7, 1905 |

JUNIORS.

| | |
|---|---|
| BLYTHE, LUCIEN HUGUET. 103 Mountain Way, Rutherford, N. J | Oct. 31, 1905 |
| COOPER, FRANK WESLEY. Laboratory Asst., Structural Materials Lab., U. S. Geological Survey, St. Louis, Mo | Sept. 5, 1905 |
| CRANE, JOSEPH SPENCER. Asst. Engr. with Wm. P. Field (Res., 179 Washington St.), Newark, N. J | Dec. 5, 1905 |
| GAY, LEON LINCOLN. Care, U. S. Geological Survey, Minidoka, Idaho | Dec. 5, 1905 |
| HENRY, SMITH TOMPKINS. Assoc. Editor, *The Engineering Record*, 1140 Monadnock Blk., Chicago, Ill | Sept. 5, 1905 |
| HODGMAN, BURT BRADLEY. 220 Broadway, New York City | Sept. 5, 1905 |
| LEEUW, HENRY. Asst. Engr., Hudson Co., Foot of 15th St., Jersey City (Res., 249 Laurel Ave., Arlington), N. J | Sept. 5, 1905 |

JUNIORS (*Continued*).

| | Date of Membership. |
|---|---|
| LIBBEY, JAMES TEMPLETON. Asst. Engr., Erie R. R., P. O. Box 176, Corry, Pa | Dec. 5, 1905 |
| SPEAR, PHILIP HICHBORN. Draftsman, N. Y. C. & H. R. R. R., 1152 E. Jersey St., Elizabeth, N. J | Dec. 5, 1905 |

## RESIGNATIONS.

### MEMBERS.

| | Date of Resignation. |
|---|---|
| BALBIN, ERNESTO JOAQUIN | December 31st, 1905 |
| FRENCH, ALFRED WILLARD | December 31st, 1905 |
| JARDINE, ALEXANDER WILLIAM | December 31st, 1905 |

### ASSOCIATE MEMBERS.

| | |
|---|---|
| RAMSEY, EDMUND PAYTON | December 31st, 1905 |

### ASSOCIATES.

| | |
|---|---|
| BARNES, WILLIAM HENRY | December 31st, 1905 |
| CRAFTS, GEORGE HENRY | December 31st, 1905 |
| PEVERLEY, RALPH | December 31st, 1905 |

## DEATHS.

BLAISDELL, ANTHONY HOUGHTALING. Elected Member, March 3d, 1880; died September 9th, 1905.

MACNAUGHTON, JAMES. Elected Member, May 5th, 1880; died December 29th, 1905.

SNYDER, FRANCIS EDWARD. Elected Member, September 6th, 1905; died December 23d, 1905.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(December 10th, 1905 to January 6th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefouille Economique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Review de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elect. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.

(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Street Railway Review*, Chicago, 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.

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Hydraulic Pumping Installation at Loan-head Colliery, near Edinburgh.* Robert Crawford. (59) Vol. 28, Pt. 1.
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Electricity in Continental Mines.* C. Smith. (45) Dec.
The Aerial Rail Hoist and Haulage System in the Joplin Region.* W. R. Crane. (45) Dec.
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New Form of Procedure for Earthwork Computations, and a Slide Rule Therefor.* C. W. Crockett. (13) Dec. 21.

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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

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# PAPERS AND DISCUSSIONS.

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# PAPERS AND DISCUSSIONS.

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## THE THEORY OF CONTINUOUS COLUMNS.

By Ernst F. Jonson, Assoc. M. Am. Soc. C. E.

To be Presented March 7th, 1906.

A column which is continuous through two or more stories differs from a one-story column in that its strength in any story is a function, not merely of its dimensions in that story, but of its dimensions in all stories. A 15-ft. section of a continuous column is evidently stronger when the adjoining sections are 10 ft. long than when they are 15 ft. long, other things being equal. Practically all columns used in buildings of more than one story are continuous.

It is the writer's purpose to develop the exact theory of continuous columns in order to deduce from it a simple method of calculating the effect of eccentric loading, both at the floor level and at an intermediate point.

The development of the equation of the elastic curve, though not new, will be given for the sake of convenience and completeness.

The bending moment in a column is (Fig. 1)

$$M = W y \quad \text{.....I}$$

where $W$ is the load, and $y$ the distance from the load line to the axis of the column.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The corresponding stress is

$$s = \frac{W a y}{I} \quad \text{.....II}$$

where $a$ is the distance to the extreme fiber, and $I$ is the moment of inertia. The corresponding elongation per unit of length is

$$e = \frac{W a y}{E I} \quad \text{.....III}$$

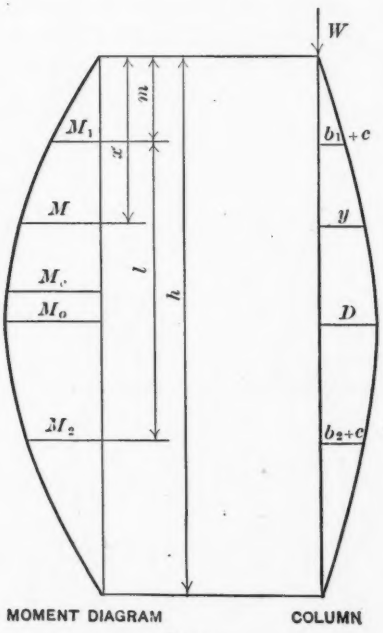



FIG. 1.

where $E$ is the modulus of elasticity. The corresponding second differential may, with sufficient accuracy, be taken as

$$\frac{d^2 y}{d x^2} = -\frac{W y}{E I} \quad \text{.....IV}$$

Hence the equation of the elastic curve is

$$y = D \sin. x \sqrt{\frac{W}{E I}} \quad \text{.....V}$$

where $D = y_{max}$.

By multiplying by $W$ we get the equation of the bending moments

$$M = M_o \sin. x \sqrt{\frac{W}{E\,I}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{VI}$$

where $M_o = M_{max.}$

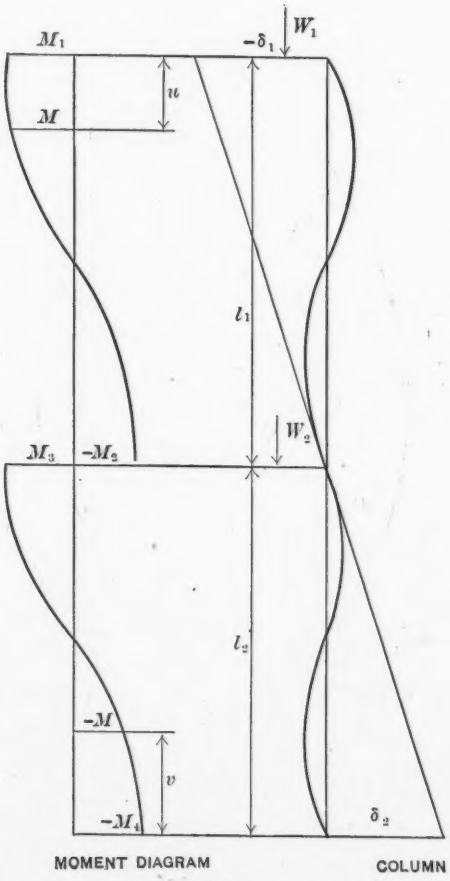



FIG. 2.

The bending of a continuous column in two adjoining stories must fulfil the following condition (Fig. 2):

$$\frac{\delta_1}{l_1} + \frac{\delta_2}{l_2} = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{VII}$$

where $\delta_1$ is the deflection of the upper end of the upper column, and $\delta_2$ that of the lower end of the lower one, both measured from the tangent to the elastic curve at the intermediate floor line, and where $l_1$ is the length of the upper and $l_2$ that of the lower column.

$$\delta_1 = \frac{1}{E I_1} \int_o^{l_1} u\, M\, d\, u \ldots\ldots\ldots\ldots\ldots \text{VIII}$$

$$\delta_2 = \frac{1}{E I_2} \int_o^{l_2} v\, M\, d\, v \ldots\ldots\ldots\ldots\ldots \text{IX}$$

where $I_1$ is the moment of inertia of the upper, and $I_2$ that of the lower column, and where $u$ is the distance from the top of the upper, and $v$ that from the bottom of the lower column.

Hence Equation VII becomes:

$$\frac{1}{I_1 l_1} \int_o^{l_1} u\, M\, d\, u + \frac{1}{I_2 l_2} \int_o^{l_2} v\, M\, d\, v = 0 \ldots\ldots\ldots \text{X}$$

Let $x - u = m$,

$$\int_o^l u\, M\, d\, u = M_o \int_o^{m+l} x \sin.\ x \sqrt{\frac{W}{E I_1}}\, d\, x$$

$$- M_o \int_o^m x \sin.\ x \sqrt{\frac{W}{E I_1}}\, d\, x - M_o\, m \int_o^{m+l} \sin. x \sqrt{\frac{W}{E I}}\, d\, x$$

$$+ M_o\, m \int_o^m \sin.\ x \sqrt{\frac{W}{E I}}\, d\ x,$$

hence

$$\int_o^l u\, M\, d\, u = M_o \frac{E I}{W} \Bigg[ \sin.\ (m+l) \sqrt{\frac{W}{E I}}$$

$$- (m+l) \sqrt{\frac{W}{E I}} \cos.\ (m+l) \sqrt{\frac{W}{E I}} \Bigg]$$

$$- M_o \frac{E I}{W} \Bigg[ \sin.\ m \sqrt{\frac{W}{E I}} - m \sqrt{\frac{W}{E I}} \cos. m \sqrt{\frac{W}{E I}} \Bigg]$$

$$- M_o\, m \sqrt{\frac{E I}{W}} \Bigg[ 1 - \cos.\ (m+l) \sqrt{\frac{W}{E I}} \Bigg]$$

$$+ M_o\, m \sqrt{\frac{E I}{W}} \Bigg[ 1 - \cos.\ m \sqrt{\frac{W}{E I}} \Bigg].$$

$$\int_o^l u\, M\, d\, u = M_o \frac{E I}{W} \Bigg[ \sin.\ (m+l) \sqrt{\frac{W}{E I}}$$

$$- l \sqrt{\frac{W}{E I}} \cos.\ (m+l) \sqrt{\frac{W}{E I}} - \sin. m \sqrt{\frac{W}{E I}} \Bigg] \ldots\ldots \text{XI}$$

From the Moment Equation VI, we find

$$M_1 = M_o \text{ sin. } m\sqrt{\frac{W}{EI}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{XII}$$

$$M_2 = M_o \text{ sin. } (m+l)\sqrt{\frac{W}{EI}} \quad \ldots\ldots\ldots\ldots\ldots \text{XIII}$$

$$\text{sin. } m\sqrt{\frac{W}{EI}} = \text{sin. } (m+l)\sqrt{\frac{W}{EI}} \text{ cos. } l\sqrt{\frac{W}{EI}} - \text{cos. } (m+l)\sqrt{\frac{W}{EI}} \text{ sin. } l\sqrt{\frac{W}{EI}}.$$

$$\frac{\text{sin. } (m+l)\sqrt{\frac{W}{EI}} \text{ cos. } l\sqrt{\frac{W}{EI}} - \text{sin. } m\sqrt{\frac{W}{EI}}}{\text{sin. } l\sqrt{\frac{W}{EI}}} = \text{cos. } (m+l)\sqrt{\frac{W}{EI}}.$$

$$\frac{M_2 \text{ cos. } l\sqrt{\frac{W}{EI}} - M_1}{\text{sin. } l\sqrt{\frac{W}{EI}}} = M_o \text{ cos. } (m+l)\sqrt{\frac{W}{EI}} \quad \ldots\ldots \text{XIV}$$

Introducing these values into Equation XI, we get:

$$\int_o^l u\,M\,du = \frac{EI}{W}\left[M_2 - l\sqrt{\frac{W}{EI}}\,\frac{M_2 \text{ cos. } l\sqrt{\frac{W}{EI}} - M_1}{\text{sin. } l\sqrt{\frac{W}{EI}}} - M_1\right]$$

$$\int_o^l u\ M\ d\ u = \frac{EI}{W}\left[M_1\left(\frac{l\sqrt{\frac{W}{EI}}}{\text{sin. } l\sqrt{\frac{W}{EI}}} - 1\right) + M_2\left(1 - \frac{l\sqrt{\frac{W}{EI}}}{\text{tan. } l\sqrt{\frac{W}{EI}}}\right)\right] \quad \ldots\ldots\ldots\ldots \text{XV}$$

Introducing this value into Equation X, we get:

$$\frac{M_1}{W_1\ l_1}\left(\frac{l_1\sqrt{\frac{W_1}{EI_1}}}{\text{sin. } l_1\sqrt{\frac{W_1}{EI_1}}} - 1\right) + \frac{M_2}{W_1\ l_1}\left(1 - \frac{l_1\sqrt{\frac{W_1}{EI_1}}}{\text{tan. } l_1\sqrt{\frac{W_1}{EI_1}}}\right)$$

$$+\frac{M_3}{W_2 l_2}\left(1-\frac{l_2\sqrt{\frac{W_2}{E I_2}}}{\text{tan. } l_2\sqrt{\frac{W_2}{E I_2}}}\right)$$

$$+\frac{M_4}{W_2 l_2}\left(\frac{l_2\sqrt{\frac{W_2}{E I_2}}}{\text{sin. } l_2\sqrt{\frac{W_2}{E I_2}}}-1\right)=0.....\text{XVI}$$

This equation is a "theorem of four moments" for continuous columns.

We also know that

$$M_2 - M_3 + M_e = 0.....\text{XVII}$$

where $M_e$ is the moment due to eccentricity of loading, the left-hand side being the positive side.

By applying these two equations to each story, from top to bottom of a continuous column, the two end moments of each section of the column are found in terms of the lower end moment of the column below, and by working back from bottom to top, introducing the values of the lower end moment, the absolute values will be found.

From Equations XII and XIII we find the maximum moment

$$M_o = \frac{\sqrt{M^2{}_1 + M^2{}_2 - 2\,M_1\,M_2 \cos.\, l\sqrt{\frac{W}{E I}}}}{\text{sin. } l\sqrt{\frac{W}{E I}}}.....\text{XVIII}$$

From Equation VI we get the distance, $h$, between two points in which the elastic curve, if prolonged, would intersect the load line.

$$h = \pi\sqrt{\frac{E I}{W}}.....\text{XIX}$$

This is Euler's formula for the length of an ideal, centrally-loaded column. The distances, $m$ and $m + l$, from the end of the ideal column to the two ends of the actual column will be, according to Equation VI,

$$m = \frac{h}{\pi}\,\text{arc sin.}\,\frac{M_1}{M}..... \text{XX}$$

$$m + l = \frac{h}{\pi}\,\text{arc sin.}\,\frac{M_2}{M_o}.....\text{XXI}$$

From these values of $m$ and $m + l$ it will be seen whether or not the maximum moment falls within the actual length of the column.

Let $M_c$ be the moment at the middle of the column. According to Equation VI

$$M_c = M_o \text{ sin. } \left(m + \frac{l}{2}\right)\sqrt{\frac{W}{E\,I}}$$

$$M_c = M_o \left(\text{sin. } m\sqrt{\frac{W}{E\,I}}\,\text{cos.}\frac{l}{2}\sqrt{\frac{W}{E\,I}} + \text{cos. } m\sqrt{\frac{W}{E\,I}}\,\text{sin.}\frac{l}{2}\sqrt{\frac{W}{E\,I}}\right) \ldots\ldots \text{XXII}$$

According to Equation XIII

$$M_2 = M_o\left(\text{sin. } m\sqrt{\frac{W}{E\,I}}\,\text{cos. } l\sqrt{\frac{W}{E\,I}} + \text{cos. } m\sqrt{\frac{W}{E\,I}}\,\text{sin. } l\sqrt{\frac{W}{E\,I}}\right) =$$

$$M_o\left(\text{sin. } m\sqrt{\frac{W}{E\,I}}\,\text{cos.}^2\frac{l}{2}\sqrt{\frac{W}{E\,I}} - \text{sin. } m\sqrt{\frac{W}{E\,I}}\,\text{sin.}^2\frac{l}{2}\sqrt{\frac{W}{E\,I}} + 2\,\text{cos. } m\sqrt{\frac{W}{E\,I}}\,\text{sin.}\frac{l}{2}\sqrt{\frac{W}{E\,I}}\,\text{cos.}\frac{l}{2}\sqrt{\frac{W}{E\,I}}\right)$$

hence

$$M_o\,\text{cos. } m\sqrt{\frac{W}{E\,I}}\,\text{sin.}\frac{l}{2}\sqrt{\frac{W}{E\,I}} = \frac{M_2}{2\,\text{cos.}\dfrac{l}{2}\sqrt{\dfrac{W}{E\,I}}} - M_c\frac{\text{sin. } m\sqrt{\dfrac{W}{E\,I}}\,\text{cos.}^2\dfrac{l}{2}\sqrt{\dfrac{W}{E\,I}}}{2\,\text{cos.}\dfrac{l}{2}\sqrt{\dfrac{W}{E\,I}}} + M_o\frac{\text{sin. } m\sqrt{\dfrac{W}{E\,I}}\,\text{sin.}^2\dfrac{l}{2}\sqrt{\dfrac{W}{E\,I}}}{2\,\text{cos.}\dfrac{l}{2}\sqrt{\dfrac{W}{E\,I}}}$$

Inserting this value in Equation XXIII, we have

$$M_c = \frac{M_2}{2\,\text{cos.}\dfrac{l}{2}\sqrt{\dfrac{W}{E\,I}}} + M_o\,\frac{1}{2}\,\text{sin. } m\sqrt{\frac{W}{E\,I}}\,\text{cos.}\frac{l}{2}\sqrt{\frac{W}{E\,I}} + M_o\frac{\text{sin. } m\sqrt{\dfrac{W}{E\,I}}\,\text{sin.}^2\dfrac{l}{2}\sqrt{\dfrac{W}{E\,I}}}{2\,\text{cos.}\dfrac{l}{2}\sqrt{\dfrac{W}{E\,I}}}$$

$$M_c = \frac{M_2 + M_o\,\text{sin. } m\sqrt{\dfrac{W}{E\,I}}}{2\,\text{cos.}\dfrac{l}{2}\sqrt{\dfrac{W}{E\,I}}}$$

Substituting $M_1$ for $M_o \sin. m \sqrt{\frac{W}{E\,I}}$, as per Equation XII, we have

$$M_c = \frac{M_1 + M_2}{2 \cos. \frac{l}{2}\sqrt{\frac{W}{E\,I}}} \quad \ldots\ldots\ldots\ldots\ldots \text{XXIV}$$

Hence it is seen that when, as is usually the case in buildings, here is but little variation in the function, $\frac{l}{2}\sqrt{\frac{W}{E\,I}}$, for any two adjoining stories, $M_c$ may be taken as proportional to the average of $M_1$ and $M_2$. This implies that we may, without great error, neglect the curvature of the moment diagram when the theorem of four moments becomes:*

$$\frac{l_1}{I_1}(M_1 + 2\,M_2) + \frac{l_2}{I_2}(2\,M_3 + M_4) = 0 \ldots\ldots\ldots \text{XXV}$$

Any possible irregularity in a column, such as a bend, an unsymmetrical distribution of the material, or a variation in the modulus of elasticity, may be reduced to an equivalent eccentricity of loading. This equivalent eccentricity, which we will call $c$, may be deduced from experiments by means of Equation V, if we substitute $c$ for $y$, $\cos. \frac{l}{2}\sqrt{\frac{W}{E\,I}}$ for $\sin. x\sqrt{\frac{W}{E\,I}}$ (provided that the specimen is supplied with round or knife-edge bearings, as it should be, in order to give reliable results), and insert the actual value of the deflection, which is

$$D = \frac{I\,(s - w)}{a\,W} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{XXVI}$$

hence

$$c = \frac{I\,(s - w)}{a\,W} \cos. \frac{l}{2}\sqrt{\frac{W}{E\,I}}$$

or

$$c = \frac{r^2\,(s - w)}{a\,w} \cos. \frac{l}{2\,r}\sqrt{\frac{w}{E}} \quad \ldots\ldots\ldots\ldots \text{XXVII}$$

where $r$ is the radius of gyration, and $w$ the average unit stress.

For immediate practical use, $c$ may be deduced from the particular building law or specification under which the work is to be executed. Thus the writer gets, from the New York building law, a $c$ for steel columns equal to $\frac{1}{16}$ in. per foot of column length, and

* See the writer's paper "The Theory of Frameworks with Rectangular Panels, and its Application to Buildings which have to Resist Wind," in *Transactions*, Am. Soc. C. E., Vol. LV, p. 413.

for cast-iron columns it becomes one-third of the radius of gyration. These values are round figures, which, in the writer's opinion, harmonize with the spirit of the law.

The actual values vary with length, radius of gyration, and distance to extreme fiber. This value for $c$ must be added to every actual eccentricity, so that Equation XVII becomes

$$M_2 - M_3 + M_e + W_1 c_1 + W_2 c_2 = 0 \ldots\ldots\ldots \text{XXVIII}$$

When there is considerable difference between the numerical values of $M_1$ and $M_2$, $M_0$ must be calculated by Equation XIX, but when they are about equal and of the same sign the simpler formula, Equation XXIV, may be used, as there will then be but little difference between $M_o$ and $M_c$. When $M_1$ and $M_2$ are of about the same numerical value, but of opposite sign, as is usually the case in buildings, $M_o$ falls outside the actual length of the column and, therefore, need not be considered, the length being seldom greater than half the distance between the maximum moments. The New York building law allows a maximum length of 64% of that distance.

From Equation XXV it is seen that when there is not much difference in the functions, $\frac{l}{I}$ and $M$, of the various stories, we may assume

$$M_1 = -M_2 = M_3 = -M_4$$

We then get the following simple formula which will cover most cases of eccentric loading occurring in buildings:

$$-M_2 = M_3 = W\left(c + \frac{b}{2}\right) \ldots\ldots\ldots\ldots \text{XXIX}$$

where $b$ is the eccentricity of the resultant load. The only condition to be fulfilled by each of these moments being

$$M_e \lessgtr \frac{I}{a}(p - w) \ldots\ldots\ldots\ldots\ldots\ldots \text{XXX}$$

$p$ being the safe compressive stress of the material.

When there are moments in two directions at right angles to each other the best way is to calculate the column in the two directions separately, and then add the resulting unit stresses. Equation XXX then becomes

$$\frac{M_{ex}\, a_x}{I_x} + \frac{M_{ey}\, a_y}{I_y} \lessgtr p - w \ldots\ldots\ldots\ldots\ldots \text{XXXI}$$

If an eccentric load be applied to a column at a point inter-

mediate between two fixed points or floor levels, Equation VII becomes (Fig. 3)

$$\frac{\delta_1}{l_1} + \frac{\delta_2}{l_2} = \frac{\alpha_1 - \alpha_2}{l_1} + \frac{\alpha_3 - \alpha_2}{l_2} \quad \text{.....XXXII}$$

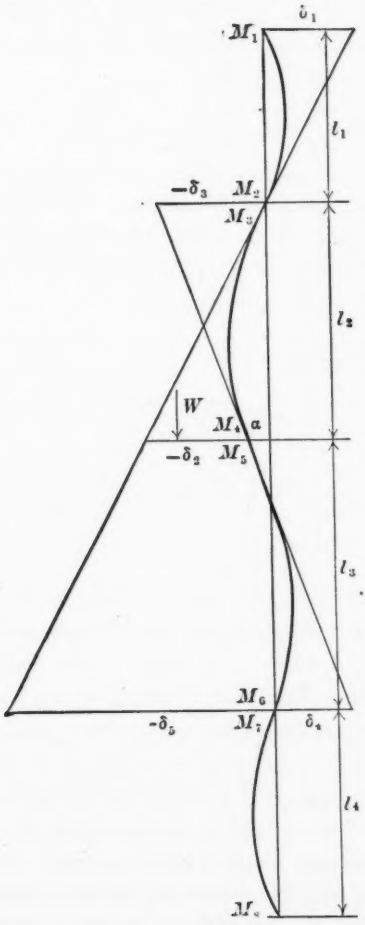



FIG. 3.

where $\alpha_1$, $\alpha_2$ and $\alpha_3$ are the deflections of three successive points at which external forces are applied. We also need an equation covering three sections or column lengths

$$\frac{\delta_1}{l_1} + \frac{\delta_5}{l_2 + l_3} = 0$$

where $\delta_5$ is the deflection of the lower end of the lower section measured from the tangent to the elastic curve at the upper end of the middle section. Hence

$$\delta_5 = \frac{\delta_2 (l_2 + l_3)}{l_2} + \frac{\delta_3 l_3}{l_2} + \delta_4$$

where $\delta_3$ and $\delta_4$ correspond in the middle and bottom sections to $\delta_1$ and $\delta_2$ of the top and middle sections. Hence

$$\frac{\delta_1}{l_1} + \frac{\delta_2}{l_2} + \frac{\delta_3 l_3}{l_2 (l_2 + l_3)} + \frac{\delta_4}{l_2 + l_3} = 0 \ldots\ldots \text{XXXIII}$$

If we now insert the various values of $\delta$ in Equations XXXII and XXXIII, we get the final equations. The exact values are given by Equations VIII, IX and XV, but, for practical purposes, the approximate value used in Equation XXV will be sufficiently accurate. The equations then become:

$$\frac{l_1}{I_1} (M_1 + 2 M_2) + \frac{l_2}{I_2} (2 M_3 + M_4) = 6 E \left( \frac{\alpha_1 - \alpha_2}{l_1} + \frac{\alpha_3 - \alpha_2}{l_2} \right) \ldots\ldots \text{XXXIV}$$

$$\frac{l_1}{I_1} (M_1 + 2 M_2) + \frac{l_2}{I_2} (2 M_3 + M_4) + \frac{l_3}{I_2 (l_2 + l_3)} (M_3 + 2 M_4) + \frac{l_3}{I_3 (l_2 + l_3)} (2 M_5 + M_6) = 0 \ldots\ldots \text{XXXV}$$

By means of Equations XXVI and XXXIV we find the various moments, as previously explained; not the absolute value, however, but a value expressed in terms of $\alpha$, which is the deflection of the unsupported point. The value of $\alpha$ is found by applying Equation XXXV to the two sections above the unsupported point and the one below it. The equation may also be applied to the two sections below and the one above, if it be reversed, that is, if $M_1$ and $M_6$, $M_2$ and $M_5$, $M_3$ and $M_4$, $l_1$ and $l_3$, exchange places.

If the column is only two sections long, one above and one below the unsupported point, and pin-connected at both ends, the above formulas cannot be used, for the problem is then a statically determined one. When the bottom end of a column is fixed, the foundation may be considered as a section of the column, the moment of inertia of which is infinite.

As to centrally-loaded columns, the writer would suggest the

following modification of the present practice, namely, that, instead of proportioning a column according to its own length alone, it would be better to take the length as one-half the distance from the middle of the story below to that of the story above. By the present practice the long columns are made relatively stronger than the short ones.

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# PAPERS AND DISCUSSIONS.

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## NEW FACTS ABOUT EYE-BARS.

By Theodore Cooper, M. Am. Soc. C. E.

To be Presented March 21st, 1906.

When, in the course of professional practice, new facts are discovered which either broaden or contradict previously accepted beliefs, it is a professional duty to present the results and deductions, after careful examination, for the common benefit of our fellow workers.

"Prove all things; hold fast that which is good."

In the execution of the superstructure of the Quebec Bridge, with its 1 800-ft. channel span, the great magnitude of the members, the high working strains, and other features of the work have demanded careful study of many points, which, in ordinary bridges, could be and have been overlooked or neglected as of small importance.

This paper will be confined to the new facts developed in regard to eye-bars.

It was a surprise and a cause of much anxiety to the writer to discover how defective was our knowledge of the eye-bar.

As a general rule, we have failed to recognize that the real elongation of an eye-bar is from out to out of pin-holes, and not

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from center to center of pins. We have carefully determined its elongation and elastic limit over a certain length of the parallel bar, and then accepted this determination as equally true when applied to the whole bar. We have assumed that a set of bars carefully bored to an exact length would all pull to an equal strain, as long as the elastic limit measured on the body of the bar was not exceeded. All these beliefs and assumptions are incorrect.

In ordinary bridges this has not been a matter of much importance, owing to the low unit strains and the small change in the deformations.

## Description of the Investigation.

In August, 1904, the manufacture of the eye-bars for the anchor arms of the Quebec Bridge was well under way when the question arose as to what clearance should be allowed between the pins and pin-holes. The eye-bars forming the tension members were 15 in. in width, from $1\frac{1}{4}$ to $2\frac{1}{16}$ in. in thickness, and of lengths from 50 to 58 ft. The pins, except in a few special cases, were 12 in. in diameter and from 8 to 10 ft. in length. The maximum joint has 58 bars on one pin.

After discussion, it was decided that the clearance necessary for the purposes of erection should not be less than $\frac{1}{32}$ nor more than $\frac{1}{16}$ in., the latter being about the proportion given to ordinary bridge pins.

As the maximum working strains are higher than in usual practice, being about 21 000 lb. per sq. in. in tension, the intensity and distribution of the local pressures from the pin to the eye of the bar became important.

The writer, after a little consideration of the problem, realized that, while the local pressure must be very great, and the pin-holes must deform elliptically, at least elastically and probably permanently under the proposed working strains, the solution could only be obtained by experiment. He then devised a method of measuring the elongation of the bar from out to out of pins, while the bar was strained to varying amounts in the testing machine.

Four bars with different clearances were prepared and tested to 12 000, 16 000, 20 000, 24 000 and 28 000 lb. per sq. in.

While the result of these tests (Nos. 646, 647, 648 and 649 of Table 2) was not fully satisfactory, owing to the crudeness of the

hurriedly made appliance, and the difficulty of reading the fine measurements in the limited space, they showed that the bars, from out to out of pins, began to elongate permanently at 12 000 lb., and that the elongation increased with each increase of strain. The amount of the pin clearance did not modify the results especially.

Was this deformation, even at low strains, a peculiarity of this "make" of bars, or had it been observed in other tests? Looking up old records, the writer found in his abstract of tests made at the St. Louis Bridge in 1872, that of 58 eye-bars put to the proof test of 18 000 lb. per sq. in., 5 showed a permanent elongation of the pin-holes of $\frac{1}{16}$ in., 52 of them $\frac{1}{32}$ in., and 1 of them $\frac{1}{64}$ in. These were iron bars.

In the Watertown "Tests of Metals" for 1883, there were found tests on 6 steel eye-bars, where the permanent elongation between pin centers at different strains is noted. They are abstracted in Table 1.

TABLE 1.—BARS, $6\frac{1}{2}$ BY 1 IN.; PINS, 5 IN.; EXCESS, 40 PER CENT. AT SIDES; END SECTION, 86 PER CENT.

| No. of Bar. | Stretch of Bar, out to out of Pin-Holes, in Inches. | | | | | | Ultimate Strength. |
|---|---|---|---|---|---|---|---|
| | 10 000 | 20 000 | 25 000 | 30 000 | 35 000 | 40 000 | |
| 4582 | 0.015 | 0.020 | ..... | ..... | 0.090 | 2.72 | 67 800 |
| 4583 | 0.010 | 0.020 | 0.025 | 0.040 | 0.060 | 2.63 | 64 000 |
| 4584 | 0.015 | 0.020 | 0.025 | 0.040 | 0.050 | .... | 65 000 |
| 4585 | 0 020 | 0.025 | 0.030 | 0.045 | 0.070 | .... | 65 850 |
| 4586 | 0.020 | 0.030 | 0.030 | 0.045 | 0.175 | .... | 64 400 |
| 4587 | 0.010 | 0.015 | 0.025 | 0.030 | 0.060 | .... | 68 290 |

It became evident, therefore, that the stretch of the eyes of eye-bars was not peculiar to the present "make" of bars, but had always occurred.

As it was important to push the construction of the work, it was decided to give the 12-in. pins $\frac{3}{64}$ in. clearance, and, for the anchor arms then under construction, to add an extra allowance of $\frac{1}{32}$ in. to the elastic elongation of each eye-bar for camber determinations; and should the further and fuller tests, then determined upon, show this to be too much or too little, the correction could be made in the cantilever arms.

The importance of the permanent stretch of the eyes, as affecting the structure in other directions, was not overlooked, but the data so far obtained were too few to furnish any definite conclusions.

Preparations were made for fuller tests, and, to eliminate the difficulties of the first method of measuring the stretch and also to get the action of each eye independently, the following method was adopted: Measure each bar from out to out of eyes, and calliper each eye longitudinally and transversely before putting it in the testing machine. Then, after straining the bar to 12 000, 16 000, 20 000, etc., lb. per sq. in., remove it from the machine and repeat the measurements.

In preparing the bars for test, it was determined to get from bars already made such a selection as would give a wide range in "heat numbers," "thicknesses," "proportions of the head," and "pin clearances." Some of the bars were specially bored to change the proportions of the head and the pin clearances, and two bars with visible flaws in the head were selected.

This selection covers Bars Nos. 705 to 718. The later bars are those which have since then been selected from time to time for the usual proof tests.

In Tables 2 and 3 all the important data of the tests so far made have been entered.

The records have been given as recorded. It will be noticed that the tape measurements from out to out of eyes, while they agree reasonably well with the sum of the elongations of the two eyes in most cases, differ in other cases. This may be partly due to errors of measurement and partly due to the measurements being taken on one side of the bar only; which, in the case of the bar being warped by the strain, would not give the exact length.

It should also be noted that in taking out and replacing the bar, if it did not get the exact position it first occupied on the pin, there would be an additional elongation of the hole before it got its proper bearings.

A number of the bars were additionally tested by trying to maintain a constant strain for several hours, to determine the effect of time. There was an increase of stretch, but it is believed to be at least partially due to the difficulties of holding a constant pressure on the machine for a long time.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 758 | $2\frac{1}{2}$ | A | 58.6 | 0.060 | 0.000 | 0.007 | 0.010 | 0.022 | 0.027 | ..... | $\frac{3}{32}$ | ..... | ..... | ..... | ..... | plates. |
| | | B Gross. | | 0.058 | 0.000 | 0.013 | 0.017 | 0.028 | 0.037 | ..... | | | | | | |

TABLE 2.

| No. of bar. | Thickness, in inches. | Head. | Excess, percentage. | Pin clearance, in inches. | Stretch of Pin-Holes, in Inches, at Varying Strains per Square Inch. 12 000 | 16 000 | 20 000 | 24 000 | 28 000 | Rupture. | Stretch, Out to Out of Pin-Holes, by Tape. 24 000 | Ultimate strength of bar. | Heat number. | Specimen Tests of Heat. Tensile strength. | Elongation, percentage. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 646 | $1\frac{1}{4}$ | A | 44 | 0.033 | 0.037 | 0.052 | 0.055 | 0.113 | 0.138 | 3.6 | ..... | 60 900 | 14 069 | 63 970 | 27 | These were the first bars tested. The results given are only approximate, as the gauge appears to have slipped, especially in 648 and 649. *Untrustworthy. |
| | | B | 44 | 0.035 | | | | | | 3.6 | | | | 65 180 | 27.5 | |
| 647 | $1\frac{1}{4}$ | A | 54 | 0.033 | 0.010 | 0.011 | 0.020 | 0.021 | 0.020 | 3.2 | ..... | 61 220 | 14 069 | 66 800 | 30 | |
| | | B | 44 | 0.031 | | | | | | 3.3 | | | | | | |
| 648 | 2 | A | 48 | 0.072 | 0.070* | 0.069* | 0.089* | 0.103* | 0.088 | 3.4 | ..... | 56 200 | 15 281 | 60 720 | 26 | |
| | | B | 57 | 0.069 | | | | | 0.038* | 3.1 | | | | 64 730 | 28 | |
| 649 | 2 | A | 39 | 0.057 | 0.012* | 0.060* | ..... | ..... | 0.114* | 5.1 | ..... | 57 000 | 15 281 | 65 320 | 25 | |
| | | B | 50 | 0.060 | | | | | | 3.4 | | | | | | |
| 705 | $1\frac{11}{16}$ | A | 52 | 0.073 | 0.014 | 0.017 | 0.033 | 0.081 | ..... | 1.7 | $\frac{3}{8}$ | 51 230* | 16 672 | 60 300 | 31 | Broke at flaw in head B. 704 cut from same bar, broke at 57 190 and pin-holes elongated 3.5 and 3 in. Cut from same bar. |
| | | B | 49 | 0.073 | 0.010 | 0.029 | 0.072 | 0.205 | ..... | 2.4* | | | | 60 300 | 32 | |
| | | | | | | | | | | | | | | 62 560 | 30 | |
| 706 | $1\frac{15}{16}$ | A | 48 | 0.064 | 0.009 | 0.044 | 0.112 | 0.266 | ..... | 3.6 | $\frac{33}{64}$ | 57 730 | 7 666 | 61 380 | 29.5 | |
| | | B | 48 | 0.073 | 0.000 | 0.035 | 0.084 | 0.207 | ..... | 3.5 | | | | 61 880 | 27 | |
| 707 | $1\frac{15}{16}$ | A | 42 | 0.082 | 0.006 | 0.013 | 0.045 | 0.148 | ..... | 3.1 | $\frac{11}{32}$ | 55 160 | 7 666 | 66 090 | 26 | |
| | | B | 46 | 0.075 | 0.010 | 0.028 | 0.055 | 0.135 | ..... | 3.0 | | | | | | |
| 708 | $1\frac{13}{16}$ | A | 40 | 0.050 | 0 004 | 0.006 | 0.012 | 0.032 | ..... | 2.5 | $\frac{1}{8}$ | 59 450 | 13 250 | 65 980 | 24 | " " " |
| | | B | 39 | 0.048 | 0.000 | 0.017 | 0.044 | 0.059 | ..... | 3.7 | | | | 66 220 | 25 | |
| 709 | $1\frac{13}{16}$ | A | 31 | 0.084 | 0.000 | 0.016 | 0.043 | 0.106 | ..... | 3.0 | $\frac{1}{4}$ | 58 340 | 13 250 | 66 760 | 26 | |
| | | B | 43 | 0.075 | 0.016 | 0.020 | 0.035 | 0.105 | ..... | 3.3 | | | | | | |
| 710 | $1\frac{9}{16}$ | A | 53 | 0.072 | 0.005 | 0.005 | 0.009 | 0.015 | ..... | 1.7 | $\frac{3}{64}$ | 60 230 | 14 069 | 63 970 | 27 | |
| | | B | 44 | 0 075 | 0.003 | 0.012 | 0.025 | 0.042 | ..... | 3.2 | | | | 65 180 | 27.5 | |
| 711 | $1\frac{9}{16}$ | A | 49 | 0.051 | 0.000 | 0.000 | 0.000 | 0.031 | ..... | 2.1 | 0 | 58 960 | 14 069 | 66 800 | 30 | |
| | | B | 48 | 0.070 | 0.000 | 0.000 | 0.000 | 0.045 | ..... | 2.6 | | | | | | |
| 712 | $1\frac{9}{16}$ | A | 46 | 0.034 | 0.002 | 0.009 | 0.014 | 0.023 | ..... | 2.5 | $\frac{3}{64}$ | 63 210 | 14 069 | | | " " " as 716. |
| | | B | 40 | 0.037 | 0.000 | 0.007 | 0.012 | 0 027 | ..... | 3.8 | | | | | | |
| 713 | $1\frac{3}{8}$ | A | 58 | 0.051 | 0.000 | 0.002 | 0.003 | 0.012 | ..... | 2.0 | $\frac{1}{32}$ | 65 220 | 4 853 | 64 380 | 23 | " " " |
| | | B | 54 | 0.054 | 0.000 | 0.000 | 0.005 | 0.006 | ..... | 1.4 | | | | 65 200 | 23 | |
| 714 | $1\frac{3}{8}$ | A | 55 | 0.064 | 0.008 | 0.008 | 0.014 | 0.037 | ..... | 2.1 | $\frac{3}{64}$ | 65 220 | 4 853 | 67 800 | 24.5 | |
| | | B | 54 | 0.063 | 0.000 | 0.002 | 0.006 | 0.024 | ..... | 2.3 | | | | | | † Broke at flaw in head B. Cut from same bar as 712. |
| 716 | $1\frac{9}{16}$ | A | 69 | 0.038 | 0.005 | 0.006 | 0.006 | 0.007 | ..... | 1.1 | $\frac{1}{64}$ | 57 800† | 14 069 | | | |
| | | B | 61 | 0.043 | 0.000 | 0.000 | 0.003 | 0.011 | ..... | ..... | | | | | | |
| 717 | $1\frac{9}{16}$ | A | 49 | 0.048 | ..... | ..... | 0.010 | 0.028 | ..... | 3.2 | $\frac{3}{64}$ | 64 360 | 14 074 | 61 780 | 29 | Cut from same bar. |
| | | B | 42 | 0.060 | ..... | ..... | 0.008 | 0.029 | ..... | 3.1 | | | | 65 440 | 25.5 | |
| 718 | $1\frac{9}{16}$ | A | 59 | 0.064 | ..... | ..... | 0.006 | 0.019 | ..... | 2.5 | $\frac{1}{32}$ | 64 870 | 14 074 | 67 000 | 28.5 | |
| | | B | 63 | 0.043 | ..... | ..... | 0.002 | 0.009 | ..... | 2.4 | | | | | | |

TABLE 3.

| No. of bar. | Thickness, in inches. | Head. | Excess, percentage. | Pin clearance, in inches. | Stretch of Pin-Holes, in Inches, at Varying Strains per Square Inch. | | | | | | Stretch, Out to Out of Pin-Holes, by Tape. | Ultimate strength of bar. | Heat number. | Specimen Tests of Heat. | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 16 000 | 18 000 | 20 000 | 24 000 | 26 000 | 35 200 | 24 000 | | | Tensile strength. | Elongation, percentage. | |
| 760 | 1¼ | A | 62 | 0.049 | 0.017 | 0.017 | 0.018 | 0.060 | 0.090 | 0.614 | 7/64 | ..... | 14 215 | | | |
| | | B | 66 | 0.054 | 0.019 | 0.020 | 0.024 | 0.048 | 0.072 | 0.606 | | | | | | |
| 761 | 1¼ | A | 56 | 0.074 | 0.009 | 0.013 | 0.030 | 0.085 | 0.136 | 0.795 | 8/64 | ..... | 14 215 | 61 180 | 24.5 | Cut from same bar. |
| | | B | 59 | 0.053 | 0.000 | 0.006 | 0.015 | 0.037 | 0.066 | 0.649 | | | | 64 020 | 26.5 | |
| 762 | 1¼ | A | 52 | 0.065 | 0.019 | 0.032 | 0.039 | 0.090 | 0.138 | 0.942 | 8/64 | ..... | 14 215 | 65 640 | 24 | |
| | | B | 59 | 0.050 | 0.009 | 0.012 | 0.016 | 0.039 | 0.055 | 0.790 | | | | | | |
| 763 | 1¼ | A | 55 | 0.054 | 0.000 | 0.008 | 0.016 | 0.033 | 0.056 | 0.821 | 9/64 | ..... | 14 215 | | | |
| | | B | 51 | 0.052 | 0.009 | 0.015 | 0.022 | 0.062 | 0.105 | 0.740 | | | | | | |
| | | | | | | | | | | Ultimate. | | | | | | |
| 798 | 2 | A | 47 | 0.047 | ..... | ..... | 0.017 | 0.035 | ..... | 3.0 | 7/64 | 56 490 | 12 987 | 60 150 | 26.5 | |
| | | B | 45 | 0.054 | ..... | ..... | 0.000 | 0.020 | ..... | 3.8 | | | | 61 860 | 29 | " " " |
| 799 | 2 | A | 46 | 0.044 | ..... | ..... | 0.011 | 0.042 | ..... | 3.8 | 7/64 | 56 740 | 12 987 | 65 180 | 26.5 | |
| | | B | 41 | 0.047 | ..... | ..... | 0.016 | 0.029 | ..... | 2.8 | | | | | | |
| 800 | 1 7/16 | A | 47 | 0.063 | ..... | ..... | 0.028 | 0.065 | ..... | 3.7 | 1/4 | 57 780 | 9 919 | 66 220 | 24 | " " " |
| | | B | 50 | 0.052 | ..... | ..... | 0.008 | 0.057 | ..... | 3.8 | | | | | | |
| 801 | 1 7/16 | A | 49 | 0.050 | ..... | ..... | 0.032 | 0.056 | ..... | 3.6 | 7/64 | 57 080 | 9 919 | 67 220 | 23.5 | " " " |
| | | B | 47 | 0.049 | ..... | ..... | 0.024 | 0.055 | ..... | 3.7 | | | | 69 220 | 23 | |
| 802 | 1 1/16 | A | 43 | 0.049 | ..... | ..... | 0.022 | 0.061 | ..... | 4.4 | 5/16 | 53 800 | 16 099 | 66 580 | 26 | 14 in. pins. |
| | | B | 47 | 0.053 | ..... | ..... | 0.027 | 0.069 | ..... | 3.9 | | | | 66 670 | 27 | Cut from same bar. |
| 803 | 1 1/16 | A | 46 | 0.050 | ..... | ..... | 0.022 | 0.050 | ..... | 4.3 | 1/4 | 54 300 | 16 099 | 68 050 | 23 | |
| | | B | 47 | 0.051 | ..... | ..... | 0.023 | 0.049 | ..... | 4.8 | | | | | | |
| 804 | 2 | A | 44 | 0.056 | ..... | ..... | 0.029 | 0.058 | ..... | 3.9 | 7/64 | 59 500 | 16 098 | 64 900 | 25 | *A* pins 12 in.—*B* pins 14 in. |
| | | B | 44 | 0.046 | ..... | ..... | 0.019 | 0.034 | ..... | 4.3 | | | | 65 230 | 25.5 | Cut from same bar. |
| 807 | 2 | A | 46 | 0.053 | ..... | ..... | 0.018 | 0.036 | ..... | 3.0 | 7/64 | 58 900 | 16 093 | 65 500 | 26 | |
| | | B | 47 | 0.033 | ..... | ..... | 0.040 | 0.079 | ..... | 4.0 | | | | | | |
| 808 | 1¾ | A | 41 | 0.056 | ..... | ..... | 0.008 | 0.043 | ..... | 3.9 | 5/64 | 58 240 | 12 891 | 63 180 | 20 | Cut from same bar. |
| | | B | 42 | 0.062 | ..... | ..... | 0.012 | 0.036 | ..... | 2.8 | | | | 64 260 | 27 | |
| 809 | 1¾ | A | 44 | 0.054 | ..... | ..... | 0.008 | 0.030 | ..... | 3.2 | 5/64 | 57 670 | 12 891 | 67 170 | 24 | |
| | | B | 48 | 0.049 | ..... | ..... | 0.004 | 0.034 | ..... | 3.1 | | | | | | |
| 822 | 1 1/8 | A | 48 | 0.052 | ..... | ..... | 0.010 | 0.019 | ..... | 3.5 | 3/64 | 60 940 | 8 690 | ..... | ..... | |
| | | B | 48 | 0.057 | ..... | ..... | 0.010 | 0.025 | ..... | 2.9 | | | | ..... | ..... | " " " |
| 823 | 1 1/8 | A | 51 | 0.044 | ..... | ..... | 0.017 | 0.022 | ..... | 3.5 | 3/64 | 60 440 | 8 690 | ..... | ..... | " " " |
| | | B | 47 | 0.070 | ..... | ..... | 0.021 | 0.034 | ..... | 4.8 | | | | ..... | ..... | |
| 759 | 2¾ | A | 58.6 | 0.046 | 0.000 | 0.007 | 0.017 | 0.012 | 0.025 | ..... | ..... | ..... | ..... | ..... | ..... | Riveted links, made of plates. |
| | | B | Gross. | 0.026 | 0.016 | 0.020 | 0.040 | 0.050 | 0.064 | ..... | ..... | ..... | ..... | ..... | ..... | |
| 758 | 2¾ | A | 58.6 | 0.060 | 0.000 | 0.007 | 0.010 | 0.022 | 0.027 | ..... | ..... | ..... | ..... | ..... | ..... | |
| | | B | Gross. | 0.058 | 0.000 | 0.013 | 0.017 | 0.028 | 0.037 | ..... | ..... | ..... | ..... | ..... | ..... | |

TABLE 2.

To illustrate the method of the testing, one detailed test is here given:

February 8th, 1905. Test No. 711. Bar, 15 by $1\frac{9}{16}$ in. Heat number, 14 069.

| Head A. | Head B. | |
|---|---|---|
| 21.46 by 1.64 in. | 21.60 by 1.62 in. | Elastic limit, 32 850 lb. |
| Excess, 49.4%. | Excess, 48.5%. | Ultimate strength, 58 960 lb. |
| Original area of bar, 23.56 in. | | Fracture, 40% silky, 60% fine granular, half cupped. |
| Fractured area of bar, 13.66 in. | | |

Diameter of testing machine pin, 11.98 in.

TABLE 4.—Detailed Observations.

| Strain per square inch, in pounds. | Diameters of Pin Holes. | | Out to out of pin-holes. | 10 ft. on body of bar. |
|---|---|---|---|---|
| | *A.* | *B.* | | |
| 0 | *T* 12.032<br>*L* 12.031 | *T* 12.050<br>*L* 12.050 | 15–$9\frac{3}{16}$ | 10 |
| 12 000 | *T* 12.032<br>*L* 12.031 | *T* 12.050<br>*L* 12.050 | " | " |
| 16 000 | *T* 12.032<br>*L* 12.031 | *T* 12.050<br>*L* 12.053 | " | " |
| 20 000 | *T* 12.032<br>*L* 12.031 | *T* 12.050<br>*L* 12.060 | " | " |
| 24 000 | *T* 12.031<br>*L* 12.040 | *T* 12.048<br>*L* 12.075 | " | " |
| 24 000 after first 2 hr. | *T* 12.031<br>*L* 12.040 | *T* 12.047<br>*L* 12.084 | 15–$9\frac{3}{32}$ | " |
| 24 000 after second 2 hr. | *T* 12.030<br>*L* 12.064 | *T* 12.047<br>*L* 12.095 | 15–$9\frac{1}{8}$ | 10–$0\frac{1}{32}$ |
| 24 000 after third 2 hr. | *T* 12.030<br>*L* 12.064 | *T* 12.047<br>*L* 12.095 | " | " |
| After rupture | *T* 12.00<br>*L* 14.12 | *T* 12.00<br>*L* 14.66 | 18–$7\frac{1}{2}$ | 12–28 |

After a number of tests had been made, from 12 000 to 24 000 lb., it was found that the important data could be obtained with less frequent removals, and thus save much time and labor. Therefore, with the exception of some special tests, the records afterward were taken only at 20 000 and 24 000 lb.

In testing two connecting links, Nos. 758 and 759, made of plates riveted together, four bars, Nos. 760-763, were used to make connection with the testing machine. The data for these members were extended over a wider range, but not carried to rupture, as the un-

supported eyes of the links began to buckle in advance of the pins at the higher strain.

On plotting the results, using the stretch of the holes after rupture as the upper limit, it was found that the stretch of the eyes at various strains per square inch followed a regular curve, differing for the different bars, but all having one general form, Fig. 1.

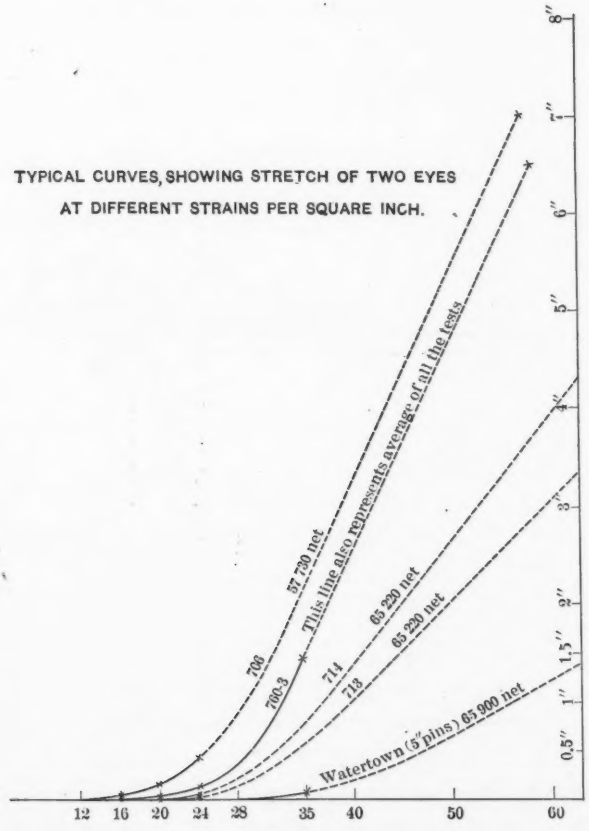



FIG. 1.

In order to save confusion by plotting each particular curve, the bars have been arranged in eight different classes, according to their stretch (covering both eyes). The average of each class is plotted in Fig. 2 on a larger scale than Fig. 1.

In addition to the previous observations, a number of the heads were scribed with fine lines, longitudinally and transversely, dividing the heads into spaces 2 in. square. After the rupture of the bars, these lines were traced and plotted, for comparison with the plots

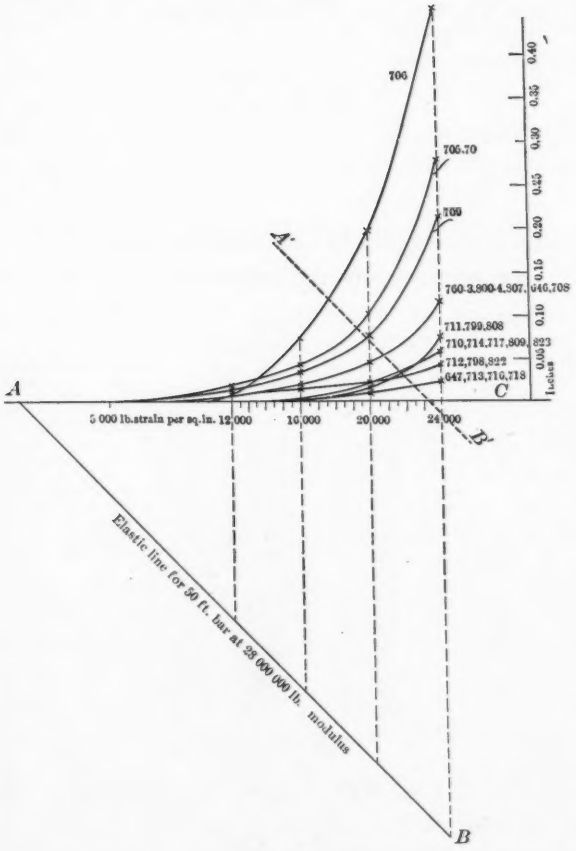


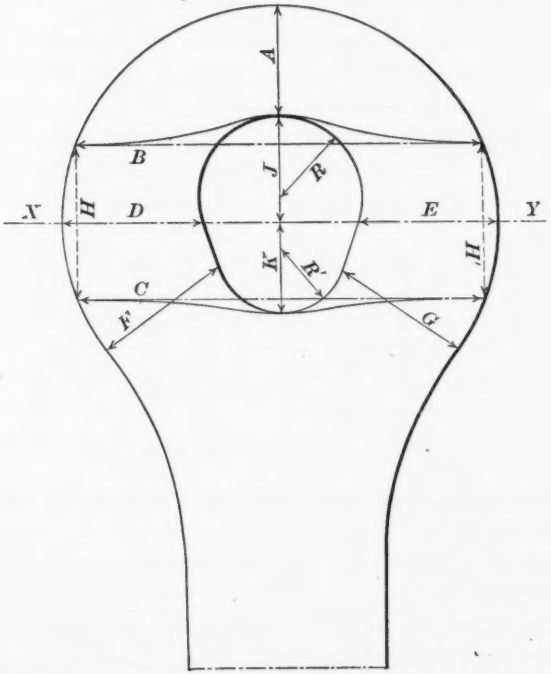

FIG. 2.

of the lines on the original bars, to determine the relative flow of the metal in different parts of the head.

It would be difficult to reproduce these tracings on a small scale. In Fig. 3 the principal and important changes from the original dimensions are shown, and the values are given in Table 5.

The line, *X Y*, is the transverse line through the center of the original pin-hole. The curved lines tangent to the elongated pin-hole are the forms taken by the straight lines tangent to the original hole before straining the bars. The upper part of the pin-hole is held to the form and diameter of the pin and has elongated more than the lower half. The diameter of the lower half has decreased by the

DEFORMATION OF HEADS OF EYE-BARS UNDER RUPTURE.




*X-Y* is line through center of original pin-hole

FIG. 3.

transverse closing in of the material under the pull. At the top of the pin the metal of the head is decreased in depth by the compression. The transverse dimensions across the eye and neck are reduced by the flow of the metal under tension. It is interesting to note that with these proportioned heads the distances, *H* and *H'*, on the outsides of the heads opposite the pins, have elongated very little or not at all, which would indicate that the periphery of the

heads at these points had not been strained much more than the elastic strength of the metal, though the bar had been strained to rupture. It should be noted that in some of the 10 and 8-in. bars this distance on one side has been decreased, indicating a compressive distortion on one side. As, in two cases, it was as much as $\frac{1}{16}$ and $\frac{5}{64}$ in., it would not appear to be due to errors in measurement, the portion of the metal most severely taxed being that portion of the intrados of the eye lying between the horizontal and curved lines at the top of the pin.

The head, No. 708 *A*, pulled unequally in the neck, one side, *G*, decreasing $1\frac{1}{4}$ in., while the other side, *F*, only decreased $\frac{3}{8}$ in., showing softer metal at one side than the other.

The difference in the pulling of the heads of No. 710 may be partly due to the fact that No. 710 *A* was thicker, having an excess of 53%, while No. 710 *B* had only 44 per cent.

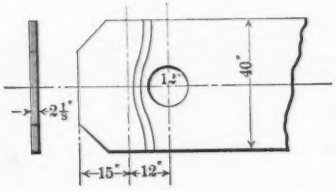



FIG. 4.

Similar observations were made upon some 8 and 10-in. bars, with like results.

The heads of the riveted links, not strained to rupture, showed a different action.

All the transverse lines below the center of the pin and those more than 12 in. above the center of the pin moved in a parallel direction, while those from the center of the pin to about 12 in. above took a curved form as shown in Fig. 4.

This was due to the absence of any neck below the pin, and to the greater stiffness of the material above the pin to resist bending.

## CONSIDERATION OF THE RESULTS.

As far as relates to the original purpose of the first tests, *viz.*, to determine the effect of the pin clearances, the tests give no definite answer. The different pin clearances vary from 0.031 to 0.084 in.

## TABLE 5.

| Bars. | Pins. | No. of Head. | Diameter of Head. | Deformation on Lines. (See Fig. 3.) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *A* | *B* | *C* | *D* | *E* | *F* | *G* | *H* | *H'* | *J* | *K* | *R'* |
| | Inches. | | Inches. | In Sixty-fourths of an Inch. | | | | | | | | | Inches. | Inches. | Inches. |
| 15 inches..... | 12 | 708*A* | 33 | −16 | −48 | −88 | −40 | −40 | −24 | −80 | +0+ | +0+ | $+1\frac{15}{64}$ | $+\frac{7}{64}$ | 5 |
| | | 710*A* | 33.7 | −16 | −12 | −32 | − 8 | −16 | −16 | −20 | +0+ | +0+ | $+1\frac{7}{16}$ | $+\frac{1}{16}$ | $5\frac{1}{4}$ |
| | | 710*B* | 33.4 | −48 | −64 | −68 | −48 | −48 | −64 | − 48 | +0+ | +0+ | $+2\frac{1}{64}$ | $+1\frac{1}{64}$ | $4\frac{3}{4}$ |
| | | 713*A* | 35 | −32 | − 8 | −20 | − 0+ | − 0+ | − 0+ | − 0+ | +0+ | +0+ | $+1\frac{3}{32}$ | $+\frac{5}{64}$ | $5\frac{3}{8}$ |
| | | 713*B* | 34.8 | − 7 | −20 | −24 | −12 | −12 | −10 | − 0+ | +4 | +4 | $+\frac{13}{16}$ | $+\frac{1}{16}$ | $5\frac{1}{4}$ |
| | | 714*A* | 34.9 | −28 | −32 | −48 | −24 | −24 | − 8 | −16 | 0 | 0 | $-1\frac{9}{16}$ | $+\frac{1}{16}$ | $5\frac{3}{16}$ |
| | | 714*B* | 34.75 | −28 | −16 | −44 | −16 | −16 | − 0 | −16 | 0 | 0 | $+1\frac{1}{2}$ | $+1\frac{3}{16}$ | $5\frac{3}{16}$ |
| 10 inches..... | $7\frac{31}{32}$ | $1\frac{3}{8}A$ | $22\frac{15}{16}$ | −22 | −19 | −14 | − 4 | −44 | − 0 | −16 | +3 | −4 | $+1\frac{13}{64}$ | $+\frac{15}{64}$ | $3\frac{21}{64}$ |
| | | $1\frac{3}{8}B$ | $22\frac{7}{64}$ | −36 | −64 | − 56 | −14 | −24 | −18 | − 3 | +3 | +3 | $+1\frac{33}{64}$ | $+\frac{15}{64}$ | $3\frac{17}{64}$ |
| | | $1\frac{1}{2}A$ | $22\frac{13}{32}$ | −28 | −27 | −45 | −12 | −23 | −18 | − 3 | 0 | 0 | $+1\frac{17}{64}$ | $+\frac{13}{32}$ | $3\frac{7}{32}$ |
| | | $1\frac{1}{2}B$ | $22\frac{15}{16}$ | −28 | −19 | −14 | −18 | −19 | − 9 | − 8 | +3 | −5 | $+1\frac{13}{32}$ | $+\frac{7}{32}$ | $3\frac{1}{8}$ |
| 8 inches..... | $6\frac{5}{16}$ | $1\frac{3}{8}A$ | $18\frac{17}{32}$ | −12 | −18 | −18 | − 8 | − 9 | − 3 | − 3 | 0 | 0 | $+1\frac{13}{64}$ | $+\frac{25}{64}$ | $2\frac{31}{64}$ |
| | | $1\frac{3}{8}B$ | $18\frac{9}{32}$ | −14 | − 8 | −16 | −10 | −10 | −11 | − 3 | −1 | +2 | $+1\frac{29}{32}$ | $+\frac{29}{64}$ | 3 |
| | | $1\frac{3}{4}A$ | $18\frac{1}{2}$ | −16 | −20 | −20 | −14 | −19 | − 5 | − 5 | +2 | +2 | $+1\frac{1}{32}$ | $+\frac{1}{2}$ | $2\frac{33}{64}$ |
| | | $1\frac{3}{4}B$ | $18\frac{3}{8}$ | −18 | − 34 | −27 | −12 | − 8 | −13 | − 2 | −1 | +6 | +1 | $+\frac{5}{16}$ | $2\frac{13}{16}$ |

— Decrease, + Increase,

While, no doubt, the pin clearance has some influence on the stretch of the eyes, it is hidden in the far greater influence of other factors. The eyes would undoubtedly elongate permanently were the pins fitted perfectly tight.

In like manner, the influence of the percentages of excess of the head is indeterminate. Bar No. 709, with excesses of 31 and 43%, gave the same result at each eye. The eight eyes of the four bars Nos. 760-3, which were made from one mill bar, gave the following elongations at 24 000 lb.:

| Head. | Excess. | Elongation. |
|---|---|---|
| 763 *B* | 51% | 0.062 |
| 762 *A* | 52 | 0.090 |
| 763 *A* | 55 | 0.033 |
| 761 *A* | 56 | 0.085 |
| 761 *B* | 59 | 0.037 |
| 762 *B* | 59 | 0.039 |
| 760 *A* | 62 | 0.060 |
| 760 *B* | 66 | 0.048 |

In these and other tests, however, there appears to be an influence due to the excess of material at the end of the eyes, which would indicate that for the best results this excess should be limited.

In the Watertown tests quoted, and in the riveted links Nos. 758-9, the frontal section in the first being 86%, and in the second 119%, of the body of the piece, the material at the end of the eye tended to buckle instead of stretching, as is the case with smaller percentages in the end of the head. The study of the present tests leads the writer to believe that a great stretch of the eyes before rupture, heretofore considered as showing a tough and tenacious material, is no more desirable than a tendency to buckle in front of the pin. The best proportions of head to resist the elongation of the eyes under the working strains cannot be decided by the present tests. It is thought probable that, for circular heads, 50% excess across the eye, thus making the end section 75% of the bar, would be a favorable proportion.

In a general examination of the tests it will be seen that the bars of the higher tensile strengths gave the better results.

Before the tests had gone very far, it was decided that the tensile

strength should be advanced, the percentages of the heads increased, and the pin clearances for the bridge bars limited to $\frac{3}{64}$ in.

While the pin clearances, excess of heads, tensile strength, and thickness of the bars, as affecting the tensile qualities, undoubtedly have some influence upon the stretch of the eyes, they do not give a full explanation.

The original bridge bars, being more than 50 ft. long, were cut in half and additional eyes made, so as to make two test bars. In one case, above mentioned, four test bars were made from one bridge bar.

The four heads of Bars Nos. 706 and 707 (same original bar) give stretches, at 24 000 lb. per sq. in., ranging from 0.135 to 0.266 in., or about as 1 to 2. That a long bar (more than 50 ft.), would differ in quality at the two extremes, does not explain the difference, for, on any assumption as to which two heads were made at the adjoining cut ends, there is still a minimum difference of stretch of 0.059 in.

Similarly, for Nos. 708 and 709 there is a range from 0.032 to 0.106 in. with a minimum difference for any two adjoining heads of 0.074 in.

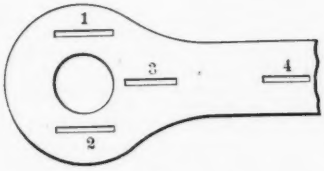



FIG. 5.

It will be noticed that the bars first tested gave the worst results (and it was fortunate that this was the case, for otherwise the necessity for a fuller series of tests might not have been recognized), presumptive evidence that more care had been taken for the later bars. The manufacturers and the inspectors assured the writer, however, that no change had been made in any of the processes of the manufacture of the later bars. It was then decided to cut samples from the two worst heads, Nos. 705 *B* and 706 *A*, and from one of the best, No. 711*A*, for nicked fractures and for tensile test, to see what the difference would be.

Samples Nos. 1 and 2 were cut from each side of the head, No. 3 from the neck, and No. 4 from the body, of the bar, as shown by Fig. 5.

The nicked fractures of the samples cut from Nos. 705 and 706 showed the same uniform fine granular structure with a clear bright luster. No difference could be detected between the several samples.

For No. 711, the samples showed a slightly coarser grain, with a suspicion of yellowish tinge in the samples from the head and neck.

These samples were examined, while fresh, by practical steel workers and experts. All agreed that they indicated nothing which would explain the different action of these heads.

The tensile tests (samples unannealed) are shown in Table 6.

TABLE 6.—TENSILE TESTS.

| Head. No. | No. of Sample. | Ultimate Strength. | Elongation in 8 in. | Reduction of area. | Fracture. |
|---|---|---|---|---|---|
| 705 *B*..... | 1 | 56 730 | 26% | 52.8% | Silky, cup. |
| | 2 | 60 870 | 25 | 53.8 | " angular. |
| | 3 | 59 260 | 26 | 56.5 | " cup. |
| | 4 | 61 680 | 28.2 | 56.6 | " angular. |
| 706 *A*..... | 1 | 62 400 | 23 | 51.9 | Silky, angular. |
| | 2 | 62 750 | 24.5 | 48.8 | " " |
| | 3 | 60 060 | 25.5 | 59.1 | " " |
| | 4 | 75 760 | 9.5 | 50.6 | " " |
| 711 *A*..... .... | 1 | 64 800 | 23.2 | 55.7 | Silky, angular. |
| | 2 | 64 960 | 19.5 | 51.7 | " ½ cup. |
| | 3 | 69 900 | 26 | 50.2 | " angular. |
| | 4 | 80 760 | 8 | 46.7 | " cup. |
| Another sample cut from the body of bar No. 711, annealed. | 5 | 60 420 | 25.8 | 55.8 | Silky. |

NOTE: As Bar No. 705 broke at a flaw in the head, *B*, the full tensile strength of the bar was not developed.

An examination of the tests for the riveted links, Nos. 758 and 759, shows that, even here, where there were no heat treatments, either of forging or annealing, the stretch of the eyes varied, the two eyes of No. 759 varying at each strain, and at 24 000 lb. the difference was 0.038 in.

An inspection of Figs. 1 and 2 shows that each class of bars, after giving a steadily increasing stretch, up to a certain point for each class, then begins to yield more and more rapidly, the bars of the higher tensile strength, as a rule, and presumably the harder

bars, resist this breaking down up to a higher point. The unequal pulling of the metal in different heads and in different parts of the same head, as shown in Table 5 and Fig. 3, shows that the metal is not homogeneous, but is softer in some bars and in different parts of the same bar. It is probable that the breaking down of the metal in front of the pin unequally is a large factor in the problem.

It is undoubtedly a great mistake to seek a soft and ductile eye-bar by using either low tensile material or softening processes.

To get the best results, we must either use steel of a higher grade, or else stretch the eyes longitudinally, cold, before the final boring to exact length, or do both. The writer believes that, with proper appliances, eye-bars can be made, which will not stretch in the eyes within the maximum working strains, without greatly increasing their cost.

As the tests here recorded have extended over a year's time, and every effort has been made to have them fairly represent the bars as manufactured from time to time, it is believed that the actual bridge bars will be better than those tested, the pin clearances and proportions of the heads being better and the tensile strength somewhat higher.

These tests do not take any account of the elastic elongation of the eyes, which no doubt occurs, but would probably be small and constant for the different bars.

## Practical Consideration and Application of the Results of the Tests.

Upon the development of the fact that eye-bars were not perfectly elastic even at low working strains, and took an increasing permanent stretch with increasing loads, it became a grave question as to "How will a series of such bars pull together?"

If two or more bars with different curves of stretch are strained to a fixed amount on the same pins, the parallelism of which is assured, the total elongation, $A\ C$, in Fig. 6, would be equal, but the permanent elongations, $B\ C$, being different, the elastic elongations, $A\ B$, must have a like difference.

The elastic elongations, $A\ B + A'\ B'$, corresponding to the total load, must be divided between the two bars proportionately to $A\ B$ and $A'\ B'$. The difference of strain on the two bars will depend

upon the ratio of the difference of permanent stretches, $B\ B'$, to the average elastic elongation, $A\ B + A'\ B' \div 2$.

The permanent stretch, at any working strain, being independent of the length of the bar, while the elastic elongation is proportionate to the length of the bar, the difference of strain in two such bars will be less as the lengths of the bars are greater.




FIG. 6.

In Fig. 1 the line, $A\ B$, is the elastic line for a bar 50 ft. long. The vertical ordinates between $A\ B$ and $A\ C$ give the elastic elongations of a bar of this length for any strain per square inch. The vertical distances from $A\ C$ to the curve of any bar gives its permanent stretch for each strain. Any line, $A'\ B'$, drawn through the curves of stretch of the several bars parallel to $A\ B$, will give, at the points of crossing, the strain on each bar for that condition of loading. The total elongations, being between two parallel lines, must be equal at these points.

For bars of other lengths, the elastic line must be changed to suit each particular length.

Although it is believed that the actual bridge bars are better than the bars tested, it will be assumed that the various bars shown in Fig. 2 cover the extremes and represent the variety of bars to be used.

By drawing any line, $A'\ B'$, parallel to the elastic line for a bar 50 ft. long, and taking off the strain on each set of bars, we can readily get the average strain for all the bars and the limits of the variation, for example:

| Bar. | No. | Strain. | Sum. |
|---|---|---|---|
| 1 | 706 | 17 600 | 17 600 |
| 2 | 705–7 | 19 200 | 38 400 |
| 1 | 709 | 19 750 | 19 700 |
| 12 | 760, etc. | 20 600 | 247 200 |
| 3 | 711 " | 21 600 | 64 800 |
| 5 | 710 " | 21 600 | 108 000 |
| 3 | 712 " | 21 800 | 65 400 |
| 4 | 713 " | 22 450 | 89 800 |
| — | | ——— | ——— |
| 31 | Average, | 21 000 | 650 900 |

Which indicates that for bars of this kind, when pulled together on pins held parallel, for an average working strain of 21 000 lb. per sq. in., the softest bar will have only 17 600 lb. per sq. in., or about 84% of the average strain; and the hardest bar will have 22 450 lb. per sq. in., or about 107% of the average—strains not disproportionate to the capabilities of the different kinds of bars.

For the longer bars, up to 58 ft.—50 ft. being the minimum length—the difference in strain will be still less.

For bars of short lengths, under high working strains, the difference in strain becomes very great, which renders the use of such bars very undesirable. It will be seen that, for much lower working strains and short bars, the bars will be subject to a like variation of strain, with long bars and the higher strains.

It is very sure, therefore, that, when using high working strains, as are required for structures of great magnitude, long bars only must be used, if this stretch of the eyes cannot be overcome.

## Camber.

For the working strain of 21 000 lb. per sq. in., it was found that a full set of bars of this kind would take a permanent elongation of about $\frac{1}{16}$ in., or $\frac{1}{32}$ in., for each eye, and this amount was provided for in all camber determinations. Further, it is thought that the probable error at the center of the channel span will not be more than $1\frac{1}{2}$ in. either way, an amount of no importance.

There are other features, connected with the action of such bars, which have been considered and provided for, but they do not come within the scope of the present paper.

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# PAPERS AND DISCUSSIONS.

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## A NEW GRAVING DOCK AT NAGASAKI, JAPAN.

### Discussion.*

BY MESSRS. CHARLES M. JACOBS, R. C. HOLLYDAY AND L. J. LE CONTE.

Mr. Jacobs.

CHARLES M. JACOBS, M. AM. SOC. C. E.—The Japanese engineers are to be congratulated on avoiding one of the great errors made in the early period of graving dock building, namely, in the width of the entrance. They have avoided this, which has detracted from the usefulness of a large number of docks in Europe; but the speaker suggests that they have committed another error in not dividing the dock by a central caisson or by gates. For example, the dock could be subdivided into two equal lengths. Looking at the photograph, Plate CII,† it will be observed that a number of torpedo boats are on the blocks, the result being that the repairs to all must be completed, at least temporarily, before floating out. The length of ordinary trading vessels on the coasts of Japan and China averages from 320 to 360 ft. Assuming that a seriously damaged vessel arrives in the dock for repairs, the entire dock is immediately closed for other work until the damaged vessel is ready for refloating. If there had been a midway caisson, or gates, the seriously damaged vessel could remain at the upper end while the outer section of the dock would remain free for docking vessels requiring light repairs, painting, cleansing, etc. Therefore the commercial possibilities and utility of the dock, with comparatively small extra expense, would

* Continued from December, 1905, *Proceedings*. See October, 1905, *Proceedings* for paper on this subject by Naoji Shiraishi, M. Am. Soc. C. E.

† *Proceedings*, Am. Soc. C. E., for October, 1905.

have been enhanced considerably by its subdivision, and it would still be available when required for ships of the largest tonnage. Mr. Jacobs.

Another point in the paper is surprising, and that is the expense of the adoption of cut stone overlying the concrete, which, according to the figures of costs given in the table, was about seven times the cost of concrete. It is beyond all question that the utilization of concrete alone for graving dock construction has long passed the experimental stage, and is assuming enormous proportions in all classes of engineering structures. The experience of the speaker, in building a short time ago two large graving docks in South Wales entirely of concrete, has proven that concrete is absolutely satisfactory in maintenance, notwithstanding that the walls of this Welsh dock had to pass through most treacherous quicksand before reaching a gravel foundation, and that the total rise and fall of the tides was 32 ft. Therefore it seems to be an unnecessary extravagance to place a granite lining on top of the concrete when the latter is just as efficient, if care be taken to enrich the outer surfaces of the concrete on the sides, altars, steps, and coping.

The speaker hopes he may also be pardoned for criticising the assertion in regard to the non-use of mechanical power, notwithstanding the statement as to the cheapness of labor in Japan. Take the cost of the dock lately completed by the speaker in South Wales, of nearly the same dimensions as the Nagasaki Dock. The contract price for the Welsh dock, built entirely of concrete, and having central gates, was $445 000, whereas the cost of the Japanese dock, notwithstanding the cheap labor, was $700 000. The cost of labor in Great Britain is very much higher than in Japan, and, with the utilization of mechanical power, the costs have proven more economical.

Another point in the paper to which attention has been called is the utilization of puzzolana mixed with the concrete to increase its imperviousness. The great difficulty in all graving dock construction is to obtain water-tightness, due to intermittent stresses on the structure. Particulars of this important feature have been omitted. If the author could give some records of filtration through the walls and invert it would add very much to the interest of the paper.

R. C. HOLLYDAY, M. AM. SOC. C. E.—The speaker, having been engaged in the construction of dry docks for the Navy Department during the past 10 years, believes that it may be of interest to state what has been done. Mr. Hollyday.

As Engineer-in-Charge, the speaker was connected with the construction of the timber dry dock at the Puget Sound Naval Station, completed about 1896, at a cost of $700 000. This dock rests on piles, with a concrete foundation under the bottom and for 7 ft. on the sides under the altars. The entrance of the dock, for 75 ft.,

Mr. Hollyday. including, of course, both gate seats, is of concrete faced with cut stone. The pumps are operated by steam engines. It is the only timber dock constructed by the Navy Department which has proved serviceable or at all satisfactory. At about the same time that this dock was being built, a timber dock was being built at the Port Royal Naval Station, South Carolina. The latter has never been satisfactory, and has seldom been used; to-day, it is scarcely in condition to be used at all, and certainly not for any first-class battleship. It is slightly smaller than the Puget Sound dock. At about the same time, Dry Dock No. 3 was being constructed at the New York Navy Yard. This dock is, approximately, of the same size as the Puget Sound dock, being about 625 ft. on the floor and 668 ft. in length over all. It was operated originally by steam-driven pumps, but a new pumping plant has recently been installed for this dock and Dry Dock No. 2, one plant being connected for both, and operated by three motor-driven 45-in. centrifugal pumps, each having an average capacity of 50 000 gal. per min. The original cost of this dock was $794 000. A great deal of trouble was encountered during its construction, and a large part of it was reconstructed almost immediately after it was completed. The cost of reconstruction was about $300 000, and even then the dock was in a very unsatisfactory condition. Three years ago the dock had to be put out of commission for about 6 months during repairs. The repairs were of a rather novel character, and pertained to the foundations near the entrance, principally in cutting off a large stream of water which entered the dock from the harbor. This flow of water undermined the material laid under the dock and under its sides to such an extent that it was likely to give way at this point. A great deal of the underlying material was quicksand, which caused most of the trouble in the construction and in its maintenance. It is hoped that this dock may be kept in commission until the completion of Dry Dock No. 4, which is now being constructed at the New York Navy Yard, and then rebuilt and made a masonry dock of concrete, lined with cut stone.

Dry Dock No. 2 at the Mare Island Navy Yard, California, which the speaker was next connected with, as Engineer-in-Charge, is now under construction. It was originally intended to be of timber, but, by Act of Congress, it was ordered that it be of stone.

The next dock with which the speaker was connected, as Engineer-in-Charge, was one of masonry at the Boston Navy Yard. This was completed during 1905. It is a masonry dock, of concrete faced with granite, and is 788 ft. in length. It was authorized at the same time as the masonry dock for the Portsmouth, New Hampshire, Navy Yard, which, by the way, is located across the river from Portsmouth, at Kittery, Me. This and the Portsmouth dock

Mr. Hollyday.

are approximately the same size; both are operated by electrically-driven pumps, and have all the accessories, in the nature of winches and capstans for handling vessels, all electrically operated. They are also provided with pneumatic pipe lines for furnishing power for work on ships in docks; with conduits for electric wires for power and for lighting; and with water piping, with outlets at frequent intervals, for attaching hose for washing down the dock and for whatever purposes water may be needed there. They are docks of the highest type yet completed, and have all the modern appliances for handling ships expeditiously, economically, and efficiently, and for doing necessary work on ships after they are docked.

The dock with which the speaker is at present connected, in the capacity of Engineer-in-Charge of construction, is Dry Dock No. 4, at the New York Navy Yard. This is to be of concrete, and little or no cut stone will be used for facing, in fact, none except at the gate seats. The dock is to be 516 ft. long on the floor by 78 ft., 542 ft. on the top by 130 ft., and will have a depth of 31 ft. of water over the sill. The contract for this dock was made during 1905, and 42 months are allowed for completion. It is to be operated by electrically-driven centrifugal pumps. Owing to the limit of cost for this dock, and also the limited space available at the New York Navy Yard, it is not possible to make it as long as the other docks which have recently been authorized by Congress for the Navy Department. It is large enough to dock the largest battleship, and it is not probable that a battleship will ever be built so large as not to be able to enter it. It is also large enough to take in the largest cruisers yet built, but it is not at all improbable that, in the future, cruisers may be built for the Navy which will be too large to enter this dock. However, Dry Dock No. 3 is long enough to take in any cruiser which is likely to be built.

Masonry docks are also being built at the navy yards at League Island, Charleston, and Norfolk. All are large docks, and of the highest type, having all the modern appliances of the Portsmouth and Boston docks.

Mr. Jacobs states that probably the Japanese made a mistake in going to the expense of facing the dock at Nagasaki with cut stone. In the speaker's opinion, this was a very important feature, and along the right lines. There are two ways of looking at this question: one from the commercial standpoint, and the other from a Government or engineering standpoint. From a commercial standpoint, it is necessary to design and build a dock which will pay a reasonable interest on the investment. A commercial concern, in building a dock, may not have the capital to invest, and, in any event, cannot afford, from a business standpoint, to make an investment which is known in advance will not yield a reasonable

Mr. Hollyday. interest. The Government and engineering standpoints are almost the same. In each case it is desirable to build the best structure possible at anything less than what might be called a prohibitive cost. From the Government standpoint, durability and efficiency are the essential features, and to have a structure which will always be available for use whenever it may be needed—a structure where extensive repairs are not continually needed. When repairs are being made it is frequently necessary to put the dock out of commission; at such a time it would not be available for use, and that might be the very time it might be needed most.

At the New York Navy Yard there are three docks, and a fourth one is under construction. Dry Dock No. 1, of masonry, with granite facing; Dry Dock No. 2, originally of timber, completed in 1890, reconstructed and built of masonry with concrete facing and metal strips for protecting the edge of the altar steps and coping, the reconstruction being completed in 1902; Dry Dock No. 3, of timber, completed in 1897. The cost of repairs on the bodies of these docks from January, 1903, to date, has been, approximately: Dry Dock No. 1, nothing; Dry Dock No. 2, $950; Dry Dock No. 3, $17 200. Although Dry Dock No. 2 has only been completed about three years, the concrete walls have begun to give trouble. Water finds its way through the walls at different points, and is first shown by the action of frost during the winter, the cracks become enlarged, the concrete is gradually spawled off the face, and the disintegration goes on. Repairs have been made to the facing, but these repairs are only regarded as temporary, patching work, and it is not believed possible to repair the dock so that there will not be future trouble of the same kind. This trouble would not have occurred had the dock been faced with cut stone, and this illustrates very clearly the point which the speaker makes in regard to facing the dock at Nagasaki with cut stone rather than concrete.

Originally, the Government built only masonry docks faced with cut stone, and the stone was frequently cut with much greater nicety than was necessary, but this was rather a matter of detail and cost. Dry Dock No. 1 at the Boston Navy Yard is of stone, and was completed in 1833. Dry Dock No. 1 at the Mare Island Navy Yard was completed in 1891; it was built by day labor, and, owing to interruption of appropriations, the work was not continuous and it took some 12 years to build it. Dry Dock No. 1 at the New York Navy Yard is of stone, and was completed about 1846. Dry Dock No. 1 at Norfolk is of stone, and was completed in 1827. These four stone docks—the first docks built by the Navy Department—may be said to be in practically as perfect a state of preservation as ever. During all these years practically no money has been spent on the body of these docks in the way of repairs, whereas, all the

Mr. Hollyday.

timber dry docks built by the Navy Department and completed within the last 10 or 12 years, with the exception of the Puget Sound dry dock, have required very extensive repairs, and one of them is practically useless to-day. This ought to show pretty conclusively that the only course open to the Government is to build the most substantial structure possible.

This Society may not be aware of the fact, but an Informal Discussion on "Dry Docks—Stone *vs.* Wood,"* had considerable to do with influencing the policy of the Government in regard to the kind of docks to be built. In 1898 Congress authorized the construction of four large dry docks—at Portsmouth, Boston, League Island, and Mare Island Navy Yards—the Portsmouth and Boston docks were to be of masonry, and the League Island and Mare Island docks were to be of timber. At that time opinion in the Navy Department was not unanimous as to the kind of dock which should be built, and there was a strong interest favoring the construction of timber docks. Congress had made up its mind to build at least two timber dry docks, against the recommendation of the Secretary of the Navy, as advised by Rear Admiral M. T. Endicott, M. Am. Soc. C. E., Chief of the Bureau of Yards and Docks, and Rear Admiral G. W. Melville, Hon. M. Am. Soc. C. E., Chief of the Bureau of Steam Engineering. There was a great deal of discussion as to the type of dock to be built, but Congress did not change its decision. Under the authority vested in him, the Secretary of the Navy proceeded to have plans prepared, advertise, and make contracts, for the construction of two stone docks at the Portsmouth and Boston Navy Yards. He also took the necessary steps for building the two timber docks authorized for the League Island and Mare Island Navy Yards, with a view to having them changed to stone docks by Act of Congress later. During this time, the subject of stone *versus* timber docks was brought up and discussed before this Society, and it was found that those who took part in the discussion strongly favored the stone dry dock. When Congress met, during the following year, members of the Naval Committee were informed that the question of stone *versus* timber dry docks had been discussed very thoroughly before this Society, and that the consensus of opinion of those who had discussed the subject was strongly in favor of stone dry docks; that Congress had made a mistake in adhering to the policy of building timber dry docks, and that it was not too late to rectify the error. The speaker was informed, by one of the most prominent members of the Naval Committee, that the discussion before this Society had as much weight as, or more than, any other one thing in influencing Congress in reversing its policy and author-

* *Transactions*, Am. Soc. C. E., Vol. XLI, p. 554.

Mr. Hollyday. izing the construction of the League Island and Mare Island docks of masonry.

It may not appear to members of this Society that this is a matter of very much importance, but to the speaker it is, in that this discussion could change the policy of the Government from a wrong principle to a right one.

Although this Society disclaims all responsibility for the facts and opinions advanced in any of its publications, its policy has always been and now is to discuss engineering subjects from an engineering standpoint. It has been against entangling alliances, of all kinds and descriptions. There has never been any suspicion of its furthering the interests of any man or set of men, and by this wise policy it has come about that its opinion is turned to as one of absolute disinterestedness.

Mr. Le Conte. L. J. LE CONTE, M. AM. SOC. C. E. (by letter).—The author was especially fortunate in having had available such a good site for a dock. Such favorable locations are very rare. Undoubtedly, the entire base of the dock should rest on solid rock, wherever possible.

The depth of water at the site of the coffer-dam, 50 ft. at high water, to bed-rock, although somewhat excessive, is often exceeded, and special precautions have to be taken on account of the great pressure on the dam when the enclosure is pumped out. A rock-filled dam is generally adopted in such cases, but practice differs with regard to the puddle core.

A semi-circular dam of small stone, properly filled with good clayey material to choke the voids on the outer slope often fulfils all requirements where that slope is not exposed to heavy weather. Where labor is so cheap and the rock excavation is seamy, as in this case, it is certainly wise to conduct the work with hand labor throughout, as the likelihood of injuring the foundation rock forbids all blasting near the lining work.

The writer is pleased with the proportions of the concrete, and with the addition of puzzolana to make impervious work, which was very desirable; he is somewhat surprised, however, to note the heavy expense for cutstone facing—$167 500—the average rate being $15 per cu. yd. in place. In these days of economical construction it is not at all clear why the altars, at least, could not have been made of high-grade concrete, if not the entire dock lining.

The writer knows that comparisons are always odious, because conditions are so different in different cases, but thinks that some broad general comparisons would not be out of place.

The new dock at Mare Island, California, now under construction, is on a pile foundation throughout, the dock foundation alone calling for 14 000 piles. The site is quite unfavorable. The dock will be 734 by 120 by 35 ft., and will have an aggregate capacity

of 114 180 cu. yd. When completed it will probably cost in the neighborhood of $1 800 000, making a capacity rate of $15.76 per cu. yd. Mr. Le Conte.

The Hamilton Graving Dock, at Malta, completed in 1893-94, was founded entirely on rock, but the formation was full of fissures, some of them 8 in. wide, and much water had to be contended with. Besides the cost of the dock proper, there were also included the cost of a factory for repairs, a 160-ton hydraulic crane, and shops and stores for repair and storage of gun mountings, etc. All this brought the cost up to $1 023 163. The dock is 558 by 126 by 44 ft., and has an aggregate capacity of 114 576 cu. yd., which makes the cost $8.93 per cu. yd. Next comes the author's dock, having a cost of $5.56 per cu. yd. of capacity, and finally, the new Hunter's Point Dry Dock, San Francisco, Cal., completed in 1903. This dock is founded throughout on rock. The lining is almost entirely of concrete, excepting the masonry piers at the entrance. The dimensions are 750 by 122 by 36 ft. = 122 000 cu. yd. Of this, 100 000 cu. yd. was rock excavation. The cost of engineering construction alone has been only $488 000, making the cost $4 per cu. yd. The altars on both sides of the dock are entirely of high-grade concrete.

This stands out in strong contrast with the Mare Island Dock, above mentioned, which is situated only a few miles further inland.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## THE INSPECTION OF TREATMENT FOR THE PROTECTION OF TIMBER BY THE INJECTION OF CREOSOTE OIL.

### Discussion.*

By Messrs. James C. Haugh, J. L. Campbell, Cliff S. Walker, E. H. Bowser and L. J. Le Conte.

Mr. Haugh.

James C. Haugh,† Esq. (by letter).—The writer submits the following observations on creosoted Southern Pine piles, brace plank, stringers, ties and caps, which have been in use on the New Orleans and North-Eastern Railroad since 1883.

The timber and piles were treated according to the specifications in use at that time by the Pascagoula Works, the requisite being 15 lb. per cu. ft. The oil used was principally "London Oil." The piles were driven in brackish water, into which the teredo does not come.

These observations represent the experience gained in 22 years of maintenance, and deal with what appear to be the causes of decay and failure.

*Round Piles and Poles.*—The depth of the injection in round piles and poles is practically limited to the sap wood. The impregnation of the sap wood of round sticks from which the inner layer of bark is not thoroughly peeled is often irregular and defective. After being subjected to the weather, this inner layer peels off, leaving

* This discussion (of the paper by H. R. Stanford, M. Am. Soc. C. E., printed in *Proceedings* for November, 1905), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Resident Engineer, New Orleans and North-Eastern Railroad.

whitish surfaces. Chips cut from these places are almost void of any oil. Even when a chip is put in one's mouth hardly a taste of the oil is perceptible. Piles or poles should have this layer of unformed sap wood thoroughly removed before treatment. Mr. Haugh.

When the heads of piles are cut to grade, an application of hot creosote oil and also asphalt thinned with oil should be applied to the cut surface. The failures of piles on structures with which the writer is familiar can be attributed to neglect to protect the heads of the piles in this way, and to the use of a 1-in. square bearded drift-bolt. The heart wood decays and leaves the sap wood sound.

*Timbers.*—Observations on timbers treated for the Lake Pontchartrain Trestle, in 1882 and 1883, show that several varieties of pine timber are still sound and in perfect preservation. No brace plank, whether sap surface or all heart from the center of the log, has decayed, and similar plank laid on the ground for 20 years is sound. In some instances the heart pieces showed but slight penetration. The stringers on this trestle were 6 by 16 in. by 30 ft., and three stringers were packed under each rail. About 6 300 pieces were used, and none has shown any decay, although the quality of the pine varied from the coarsest loblolly, with one sap surface, to the closest and best quality of long-leafed close-grained yellow pine, practically free from sap.

The penetration of oil in these different qualities of pine varied greatly. The loblolly and other coarse-grained stringers show that timber of this quality absorbed a large percentage of oil, and the close-grained yellow pine a much smaller percentage, probably more than 20 lb. per cu. ft. for the coarse-grained, and less than 10 lb. for the close-grained, pine. The caps used were 12 by 14 in. by 14 ft.; the ties, 6 by 8 in. by 9 ft. The guard-rails were 5 by 8 in. and all were of the same varied qualities of pine. Timbers of the same size were treated together.

There were more failures in caps than in timbers of any other size. This, in the writer's opinion, was due to the size of the timbers not admitting of thorough seasoning, consequently, they "checked" afterward. This checking extended beyond the point to which the creosoted oil penetrated.

Almost without exception, the caps had the heart core at or near the center, and the circular grains were not cut across in being sawn, as was the case with stringers, plank and halved and quartered ties.

The stringers were halved from a log in sawing, and all the grains were cut across on the heart face. This permitted more thorough seasoning and the penetration of the oil into the heart face.

The ties were what are known as pole, halved and quartered ties. The pole ties having the heart core in the center also failed by checking beyond the point to which the oil had penetrated.

Mr. Haugh.

The halved and quartered ties having the grain cut across admitted of more thorough seasoning and penetration of the oil, and, when placed in the structure with the "sap side" up, there were few cases of decay.

The halved or quartered guard-rails showed the same durability as the ties. The pieces with the heart core in the center failed.

It would seem from these observations that similar timbers, in which the heart core is in the center, cannot be so thoroughly seasoned as to prevent checking and internal decay, even when the creosoted sap surfaces protect it, and that timbers halved and quartered permit of the proper seasoning, and, even where the quantity of oil absorbed is slight, are still sound.

TABLE 2.—REPORT OF TRANSVERSE TEST OF CREOSOTED PINE STRINGER, NO. 1, FROM THE NEW ORLEANS AND NORTH-EASTERN RAILROAD.

Breadth = 6 in. Height = 15½ in. at center. Length between supports = 132 in. Maximum fiber distance = 7.75 in. Moment of inertia = 1 861.9. Load applied in increments of 3 000 lb. Riehlé testing machine used. Time, about 1 hr. 30 min. Date, June 23d, 1905.

| Load, in pounds. | Stress per square inch in outer fiber. | Deflection. Reading: R. | L. | Total, in inches. | Set. Reading: R. | L. | Total, in inches. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| ..... | ..... | 0.10 | 0.13 | ..... | ..... | | ..... | 11 hard rings to the inch. |
| 3 000 | ..... | 0.16 | 0.16 | 0.045 | ..... | | ..... | |
| 6 000 | ..... | 0.20 | 0.21 | 0.09 | ..... | | ..... | |
| 9 000 | ..... | 0.25 | 0.26 | 0.14 | ..... | | ..... | |
| 12 000 | ..... | 0.30 | 0.31 | 0.19 | ..... | | ..... | |
| 15 000 | ..... | 0.36 | 0.36 | 0.245 | ..... | | ..... | |
| 18 000 | 2 472 | 0.41 | 0.40 | 0.29 | ..... | | ..... | Elastic limit. |
| 21 000 | ..... | 0.49 | 0.48 | 0.37 | ..... | | ..... | For 14 ft. distance between supports, load at elastic limit would be 14 130 lb. |
| 24 000 | ..... | 0.56 | 0.55 | 0.44 | ..... | | ..... | |
| 27 000 | ..... | 0.65 | 0.62 | 0.52 | ..... | | ..... | |
| 30 000 | ..... | 0.79 | 0.74 | 0.65 | ..... | | ..... | |
| 33 000 | ..... | 0.94 | 0.88 | 0.845 | ..... | | ..... | Maximum, 28 500 lb. |

| | Actual load, in pounds. | Deflection, in inches. | Stress per square inch in outer fiber. |
|---|---|---|---|
| Elastic limit..... | 18 000 | 0.29 | 2 472 |
| Maximum..... | 36 300 | 0.845 | 4 990 |

Modulus of elasticity = 1 597 000 lb. per sq. in., at 18 000 lb. load.

Possibly boring a hole longitudinally through the center of timbers containing the heart core would allow better seasoning, prevent to some extent the checking of the surfaces, and admit of the penetration of the oil to the inner rings cut. This boring is now done, at a number of saw-mills, in timbers 20 ft. long. Mr. Haugh.

TABLE 3.—REPORT OF TRANSVERSE TEST OF CREOSOTED PINE STRINGER, NO. 2, FROM THE NEW ORLEANS AND NORTH-EASTERN RAILROAD.

Breadth = 6 in. Height = 15½ in. at center. Length between supports = 132 in. Maximum fiber distance = 7.75 in. Moment of inertia = 1 861.9. Load applied in increments of 3 000 lb. Riehlé testing machine used. Time, about 1 hr. 30 min. Date, June 23d, 1905.

| Load, in pounds. | Stress per square inch in outer fiber. | Deflection. Reading: R. | Deflection. Reading: L. | Deflection. Total, in inches. | Set. Reading: R. | Set. Reading: L. | Set. Total, in inches. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| ..... | ..... | 0.10 | 0.15 | ..... | 0.10 | 0.15 | ..... | 6 rings to the inch. |
| 3 000 | ..... | 0.14 | 0.20 | 0.045 | 0.10 | 0.15 | 0 | |
| 6 000 | ..... | 0.19 | 0.24 | 0.09 | 0.10 | 0.15 | 0 | |
| 9 000 | ..... | 0.24 | 0.29 | 0.14 | 0.10 | 0.15 | 0 | |
| 12 000 | ..... | 0.28 | 0.33 | 0.18 | 0.10 | 0.15 | 0 | |
| 15 000 | ..... | 0.33 | 0.38 | 0.23 | 0.10 | 0.15 | 0 | |
| 18 000 | ..... | 0.37 | 0.42 | 0.27 | 0.10 | 0.15 | 0 | |
| 21 000 | ..... | 0.42 | 0.46 | 0.315 | 0.10 | 0.15 | 0 | |
| 24 000 | ..... | 0.45 | 0.53 | 0.365 | 0.10 | 0.15 | 0 | |
| 27 000 | 3 708 | 0.51 | 0.57 | 0.415 | 0.10 | 0.15 | 0 | Elastic limit |
| 30 000 | ..... | 0.56 | 0.64 | 0.475 | 0.10 | 0.17 | 0.01 | For 14 ft. distance between supports, load at elastic limit would be 21 200 lb. |
| 33 000 | ..... | 0.63 | 0.74 | 0.56 | 0.12 | 0.17 | 0.02 | |
| 36 000 | ..... | 0.70 | 0.83 | 0.64 | 0.14 | 0.20 | 0.045 | |
| 39 000 | ..... | 0.75 | 0.90 | 0.70 | ..... | ..... | ..... | |
| 42 000 | ..... | 0.82 | 1.00 | 0.785 | ..... | ..... | ..... | |
| 45 000 | ..... | 0.90 | 1.14 | 0.895 | ..... | ..... | ..... | Maximum, 38 900 lb. |
| 48 000 | ..... | 1.12 | 1.45 | 1.16 | ..... | ..... | ..... | |

| | Actual load, in pounds. | Deflection, in inches. | Stress per square inch in outer fiber. |
|---|---|---|---|
| Elastic limit..... | 27 000 | 0.415 | 3 708 |
| Maximum..... | 49 600 | 1.16 | 6 600 |

Modulus of elasticity = 1 698 000 lb. per sq. in., at 27 000 lb. load.

Where the sizes of timbers required are such that proper seasoning is difficult, if not impracticable, built-up members, which admit of this, should be used.

The cubic contents of the charge to be treated and the measurement of the quantity of oil injected should be ascertained as closely

Mr. Haugh. as practicable, but, in the case of round pine piles, the sap wood varies from, say, 1 in. thick at the butt, in some piles, to 3 in. thick in others, so that the quantity of oil each pile in a load will take varies greatly, and, if thoroughly seasoned and protected, both are equally durable. The same remarks apply to square pine timbers and in these the absorption also varies greatly. The presence of water and the dilution of the fluid should receive close attention.

Mr. Stanford's remarks as to the inspection of certain piles, in July, 1905—five piles being eaten by worms—leads the writer to attribute the failure of the oil to penetrate certain sections to improper "peeling" of the piles.

TABLE 4.—REPORT OF TRANSVERSE TEST OF CREOSOTED PINE STRINGER, NO. 3, FROM THE NEW ORLEANS AND NORTH-EASTERN RAILROAD.

Breadth = 6 in. Height = 16 in. at center. Length between supports = 132 in. Maximum fiber distance = 8 in. Moment of inertia = 2 048. Load applied in increments of 3 000 lb. Riehlé testing machine used. Time, about 1 hr. 30 min. Date, June 24th, 1905.

| Load, in pounds. | Stress per square inch in outer fiber. | Deflection. Reading: R. | Deflection. Reading: L. | Deflection. Total, in inches. | Set. Reading: R. | Set. Reading: L. | Set. Total, in inches. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| ..... | ..... | 0.05 | 0.08 | ..... | 0.05 | 0.08 | ..... | 5 hard rings to the inch. |
| 3 000 | ..... | 0.10 | 0.13 | 0.05 | 0.05 | 0.08 | 0 | |
| 6 000 | ..... | 0.15 | 0.17 | 0.095 | 0.05 | 0 .08 | 0 | |
| 9 000 | ..... | 0.21 | 0.21 | 0.145 | 0.05 | 0.08 | 0 | |
| 12 000 | ..... | 0.25 | 0.26 | 0.19 | 0.05 | 0.08 | 0 | |
| 15 000 | ..... | 0.30 | 0.31 | 0.24 | 0.05 | 0.08 | 0 | |
| 18 000 | ..... | 0.36 | 0.37 | 0.30 | 0.05 | 0.08 | 0 | |
| 21 000 | 2 700 | 0.42 | 0.41 | 0.35 | 0.05 | 0.08 | 0 | Elastic limit. |
| 24 000 | ..... | 0.48 | 0.47 | 0.41 | 0.05 | 0.09 | 0.005 | For 14 ft. distance between supports, load at elastic limit would be 16 500 lb. |
| 27 000 | ..... | 0.55 | 0.52 | 0.47 | 0.08 | 0.10 | 0.025 | |
| 30 000 | ..... | 0.61 | 0.59 | 0.535 | 0.08 | 0.10 | 0.025 | |
| 33 000 | ..... | 0.67 | 0.65 | 0.595 | 0.09 | 0.11 | 0.035 | Maximum, 32 100 lb. |
| 36 000 | ..... | 0.75 | 0.72 | 0.67 | ..... | ..... | ..... | |
| 39 000 | ..... | 0.85 | 0.82 | 0.77 | ..... | ..... | ..... | |

| | Actual load, in pounds. | Deflection, in inches. | Stress per square inch in outer fiber. |
|---|---|---|---|
| Elastic limit..... | 21 000 | 0.35 | 2 700 |
| Maximum..... | 40 900 | 0.77 | 5 260 |

Modulus of elasticity = 1 405 000 lb. per sq. in., at 21 000 lb. load.

Mr. Haugh.

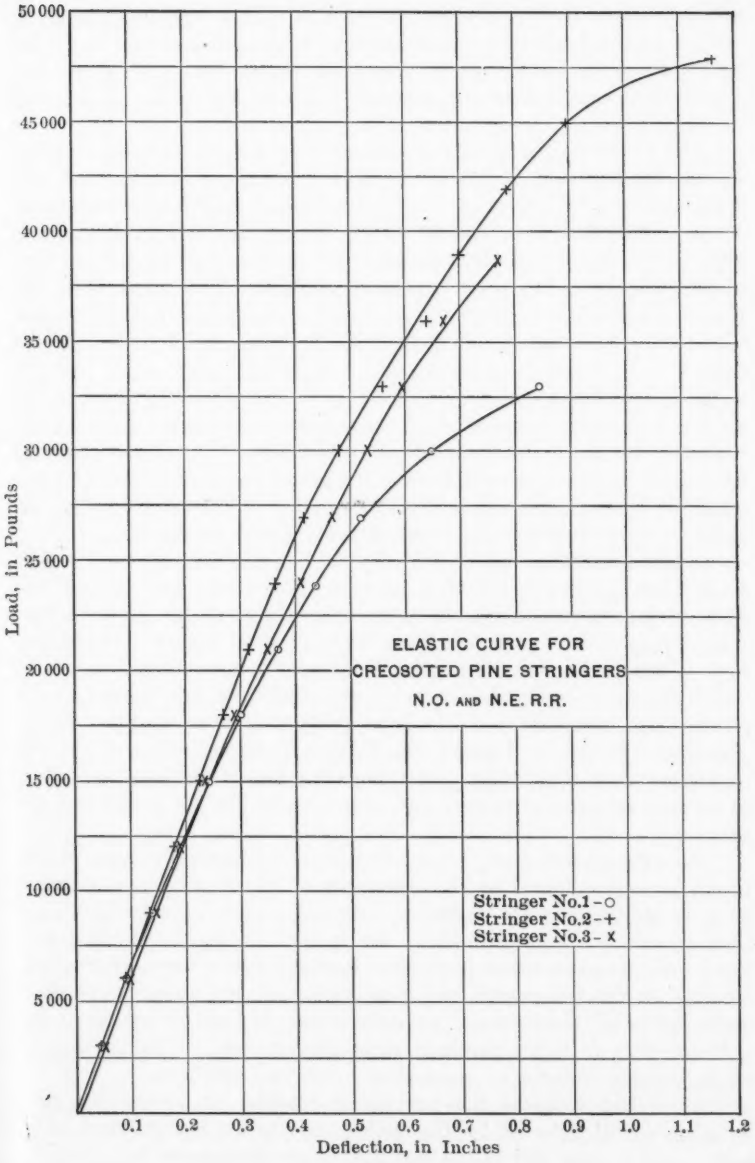



FIG. 1.

Mr. Haugh. The proposed specifications, and the remarks as to air-seasoning, seem to cover the requirements, and the writer would add that if timber is cut from logs which have been floated in creeks or rivers and have been in the water for weeks or months and then air-seasoned, the most desirable seasoning will be obtained. At several creosoting works, this is practicable.

The tests of three pieces of creosoted pine stringers, which were in use on the Lake Trestle from 1883 until taken out in 1905 for test, are given in Tables 2, 3 and 4, and Fig. 1 is a diagram of these tests. The piece, No. 1, was about the average for close-grained yellow pine, having 22 alternate hard and soft grains per inch. The other two pieces are the coarse-grained pine. The penetration of the oil in No. 1 was slight; Nos. 2 and 3 had taken the oil freely. The tests were made by Professor W. B. Gregory, of Tulane University.

Mr. Campbell. J. L. CAMPBELL, M. AM. SOC. C. E. (by letter).—Mr. Stanford's statement that the extent to which creosote oil preserves timber is measured by the quantity of oil and the depth of penetration, while true to the point of saturation with a given grade of oil, should be qualified by the observation that the quality of the oil has quite as much to do with the results as the quantity and penetration.

In the prevailing grade of oil used in the United States the creosote or preserving element constitutes probably not more than 30% of the volume, from which it follows that about 70% of the injection is of no benefit, and that a large total injection is necessary to secure the required quantity of real preservative.

If the oil was refined to a point where the preservative and non-preservative elements were in a proportion inverse to that above given, as obtains in Europe, the life of treated timber would be prolonged very materially. The use of a better grade of creosote opens a most promising field for improvement in the treatment of timber.

The author's statement, that heart wood is practically impervious to oil, is not confirmed by the experience of the El Paso and Southwestern Railroad in its creosoted long-leaf yellow pine bridge timbers, in which the percentage of sap is very small. Stringers having no sap whatever show a required and satisfactory penetration of oil. As to the percentage and penetration of the preservative element in the oil, the writer is not able to say, but there is nothing to indicate that it is all retained near the surface. This timber is treated under contract by creosoting works in Louisiana.

The writer believes the prevailing method of measuring the quantity of oil injected by the tank gauge to be the simplest and best. Leaky pipes and valves and inaccurate gauges are not a valid argument against the method, but rather are favorable to it, as

pipes and valves can be and should be maintained practically tight to prevent useless waste. Mr. Campbell.

From the author's illustration of the method of measurement by weight, it is quite evident that several very material assumptions have to be made, the possible invalidity of which may explain the inadmissible difference between 22.4 lb. per cu. ft. by tank measure and 13.5 lb. per cu. ft. by estimated weight measure.

Certainly, a system of pipes and valves which will permit the escape and loss of 8.9 lb. of oil out of a total of 22.4 lb. ought to be replaced immediately.

The writer is heartily in favor of air- *vs.* steam- seasoning whenever practicable. He finds that treated ties fail because of disintegration due to brittleness induced by the steam-cooking process of preparation for treatment. Treating plants, however, are generally located in the timber belts, where the normal humidity is great and the air-seasoning process quite slow.

El Paso, Tex., the center of the arid Southwest, with its numerous railway lines (several of them transcontinental), and direct competitive connection with vast, though distant, timber belts, would be an ideal place for the air-seasoning process for timber treatment.

With a grade of oil containing, say, 75% of preservative element, thorough air-seasoning, and proper injection of a sufficient quantity of creosote, sound timber, so treated, should lose very little of its strength and elasticity, and be good for 45 years under ordinary conditions.

CLIFF S. WALKER,* ESQ. (by letter).—The author has given the subject much thought and close investigation, and in the writer's opinion is on the right line to attain the end to be desired by both producer and consumer of creosoted material. Only by thorough injection can timber be preserved, and to approximate that standard of excellence should be the aim of every manufacturer. Poorly treated material has in the past greatly retarded increased demand for preserved timber, and can but injure the future prospects of a growing industry. Any system that tends to give the manufacturer all the profit to which he is entitled, and at the same time protects the consumer, is to be encouraged. The only possible objection to the author's proposed method is that the natural variation in density of timber might cause this method of ascertaining the price to be so risky that in many cases the margin of safety which must be figured would make the cost prohibitive. Mr. Walker.

To arrive at a fair basis would require long and close scientific investigation, and reports on temperatures, pressures, etc., day and night, should not be left to workmen who lack proper training, or even might be ignorant, lazy or malicious.

*President, Southern Creosoting Company, Ltd.

Mr. Walker. The writer differs slightly with the author on some points of his proposed specification, principally with the idea of reducing cost of production. In practice, the writer has never found any advantage in treating timber of uniform size and section at one time, and favors applying the higher temperatures, regardless of size of timber, with the intention of shortening the period of treatment. Close observation has convinced him that a better impregnation of timber is secured.

The writer also thinks that the arbitrary specification for oil is unreasonable, as good results have been obtained with various oils differing materially in specific gravity and fractional distillation; and, as the demand for treated timber increases, every possible source of supply for heavy oil of coal-tar should be open.

On the whole, though, the writer is so heartily in favor of the author's views and conclusions, that he would be highly gratified could he find the time to experiment thoroughly on the lines suggested, using the plant of the Southern Creosoting Company in that work, and thus view results obtained, not in the laboratory, but in actual practice, under all conditions and with all classes of material.

Such investigation and experimentation by one so familiar with the work and the conditions to which the finished product is to be subjected would prove of exceeding value.

Mr. Bowser. E. H. Bowser, M. Am. Soc. C. E. (by letter).—This is a much needed paper, in that it touches upon points relating to the subject of creosoting, which, although they have been discussed for many years, are little nearer solution than they were when this method of treating timber was first established.

From their very nature, some of the details of timber treatment can never be brought to any great degree of refinement, though the methods can be improved.

It is well known that sap wood will receive very much more oil than heart wood; that loblolly and old field pine will receive more than long-leaf yellow pine; that in a long pile the small end will receive a greater proportion of oil than the large end, and that the more natural seasoning the material has had, the more rapidly the oil will enter it, and the greater quantity it will hold.

Even after a careful selection of the timber, the quantity of oil per cubic foot injected into each piece will vary greatly, and only a general average treatment can be given, as it is impossible to determine in advance just what material to select for each charge.

By proper inspection, the results of a treatment can be greatly modified and brought much nearer what they should be than with a haphazard method of treating a load without regard to the size, seasoning, or kind of timber.

In considering the inaccurate methods used at present and the

proposed change for determining the quantity of oil injected into timber, all clearly presented in the paper, no very definite results obtained from any long-continued and exhaustive experiments can be given, on account of this part of the subject not having been thoroughly investigated, as yet. Mr. Bowser.

A few experiments which show unexpected results, while they are valuable in that they blaze the lines along which investigation should be made, are not conclusive, and sometimes may even be reversed by further experiments.

The writer will take up some of the causes of the discrepancies in present methods, mentioned in the paper, and a few additional causes, under separate heads.

*Calculating the Volume of the Material.*—In getting the cubic contents of piles, it is the rule to use the diameters of the large and small ends, measured to the nearest inch. It is not often that the measurement is made to the nearest half inch, and taking intermediate measurements is almost unknown.

The taper of the southern pines is remarkably regular, when proper allowance is made for what is known as "swell butts," and in extra long piles, for the more rapid taper, near the point, on account of the small end having been cut above the branch line.

"Swell butts" are caused by the woodman cutting the tree very close to the ground, in order to get a sufficient diameter, or a longer pile.

To prevent careless measurements of the large end of poles or piles, the Southern Bell Telephone Company, and some others, specify the circumferential measurement 3 ft. from the end.

As the result of a number of measurements taken at different times, and from piles cut in different localities in Mississippi and Louisiana, it has been found by the writer that the taper is very close to an increase of 1 in. in diameter, from the point toward the butt, for every 10 ft. of length.

While the lack of refinement in measuring round timber is often discussed, the errors resulting from taking the mill measurements for unsized sawn timber, in calculating the contents, is usually neglected—in fact, the writer has seen millions of feet of material of this class treated, and not one stick was calculated by the actual dimensions of the cross-section; and, only when the excess in length was over 1 ft., was it usually taken into account; nor would he recommend an exact measurement unless it was stipulated in the specifications, as the bid of the contractor making the treatment is based on the mill size of the section, and the judgment of the inspector is allowed to govern what would be excessive length.

For most purposes for which rough sawn timber is used, the sticks are cut to lengths and the ends squared at the works before treatment, but such is not always the case.

Mr. Bowser.

All mills in the Central South set their gauges to saw from $\frac{1}{8}$ to $\frac{3}{8}$ in. full, and this fullness often amounts to $\frac{1}{2}$ in. and even more. This is done to allow for shrinkage after seasoning, irregularities in the alignment of the carriage track, and for the "running" of the saw. Freshly sawn timber will average at least $\frac{1}{4}$ in. full, which in a 12 by 12-in. stick means 4% more than the actual contents. In thin material, such as plank, the variation will average much more. In length, the pieces are seldom cut less than 3 in. full at the mill, and are often more than 6 in. longer than the rated length. Few inspectors will receive a stick which is the least scant in cross-section or length, and, on this account, the variation between the actual and the calculated contents of a charge of sawn timber always makes the cubic content less than it should be.

In the writer's opinion, piles measured at points and butts by the "give and take" method, to the nearest half inch, give much more accurate results than sawn timber taken at the size for which it was cut.

*Allowable Quantity of Water in the Oil.*—The specifications for oil, quoted in the paper, are, as far as the water is concerned, specifications by which oil should be bought; and it is the common custom to allow 2½% of water, and no more, in the oil from the manufacturer, but, in the writer's judgment, a margin should be allowed for water taken into the oil during the process of treatment at the creosoting works, and at least 5% should be allowed, provided the quantity greater than 2½% is compensated for by an extra injection of oil.

Many specifications allow a maximum of 8%, and this quantity does not seem to be excessive, as the quantity of water would be offset by deeper penetration or by putting the proper quantity of oil in the same space that it would occupy if there were not more than 2½% of water.

With present methods of manipulation, it is not practicable to keep the water to a 2½% limit at all times. Getting water out of oil is expensive, and rigid specifications would, no doubt, cause a corresponding increase in prices if the inspection for water was also rigid.

*Waste During Injection, and Loss Due to Reduction of Volume of Oil under Pressure.*—Very nearly all the waste oil can be accounted for by collecting the leakage in large pans made for the purpose, and emptying it into the measuring tank at the completion of the treatment. If there is a leak in the steam coils, this is easily discovered, and the set of coils in which it is found can be cut out of service and throttled at the end where the oil would pass out.

The writer has no data at hand showing the elasticity of the oil, and can form no idea as to the reduction of the volume caused by

the pressure to which it is subjected, but it probably does not amount to very much. Mr. Bowser.

In some specifications the payment for the quantity of oil injected is based on the difference between the readings of the gauge before the oil is turned on the charge and after it is pumped back into the measuring tank. This eliminates any errors due to compression, the oozing out of the oil from the wood after the pressure is released, and very nearly all the loss of oil by waste, if the waste is properly collected.

Such provisions were made in the specifications written by J. F. Coleman, M. Am. Soc. C. E., for the treatment of material for the New Orleans docks.

*The Prevailing Method of Measuring the Quantity of Oil Injected.*—A number of the creosoting works have measuring tanks 20 ft. in diameter, but tanks proportioned to the sizes of the cylinders would give more uniform results. It has been the writer's experience that a well-constructed sliding gauge, kept in good condition, can be read within less than ¼ in., and a 6-in. treatment from a 20-ft. tank ought not to vary more than 3% either way.

The heavier the treatment, or the larger the cylinder and load, the less will be the variation.

A tank, 30 ft. deep, with a diameter great enough to give a capacity of one and one-quarter times that of the empty cylinder which it supplies, would be about the right proportion, and, with a properly made sliding gauge, ought to give results within 1% of a refined measurement.

This rule would give, for a cylinder 6 ft. in diameter and 100 ft. long, a measuring tank 11 ft. in diameter; and, for a cylinder 9 ft. in diameter and 100 ft. long, a tank 16 ft. in diameter.

The accuracy of the sliding gauge will depend upon the size of the horizontal section of the float, the frictional resistance in the bearings of the pulleys, the pliability of the wire connecting the float with the sliding pointer, and the proper balancing of the pointer so that the guides will not clamp on the gauge-board.

The larger the float the less the distance it will be lifted out of the oil by the friction of the pulleys and the pointer guides.

The pulleys, of course, should be large enough in diameter to prevent the tendency of the wire to form a hook. A light, well-made chain would give better results than a wire.

The wind playing on a long wire running from a measuring tank to a gauge inside the cylinder shed has been observed to make a variation in the reading of the gauge.

The difference between the quantity of oil injected into sawn timber, as indicated by present methods of measurements, may often vary as much as 10% less than the actual amount. This is due to the following causes:

Mr. Bowser.

The difference between 8.7 lb. per gal., the weight of the oil at about 75° fahr., which is generally used in calculating the quantity of oil to be injected, and 8.33 lb. per gal., the weight of the oil at 180° fahr., which is about the temperature of the oil in the measuring tank, making a shortage of oil amounting to 4%; the difference in the volume of the oil when in the measuring tank and when under pressure in the cylinder; the running out of some of the oil from the timber after the pressure is released; the fullness of the timber not being taken into account; and the loss by waste, which can be kept very low if proper care is used. There can be considerable loss if care is not taken in analyzing for water.

With proper specifications and proper inspection, all the foregoing discrepancies can be reduced to a very small percentage.

*Proposed Method, of Estimating the Quantity of Oil Injected, by Full-Sized Test Pieces.*—The most radical departure brought forward in Mr. Stanford's paper is the proposed change in the method of determining the quantity of oil injected.

The quantity of oil which different pieces of timber will absorb varies greatly with the texture, the quantity of resin in the ducts, the quantity of sap wood, the seasoning, the relation between thickness and breadth, and the length.

It is so well known that sap wood will absorb very much more oil than heart wood that nothing further need be said. The variation of the quantity of oil that can be absorbed on account of different degrees of seasoning is very great.

In a 16-lb. treatment, at one works, a load of branch pine piles, 50 ft. long, which had been seasoning for 6 or 8 months, was given a treatment in about one-third the time usually taken for freshly cut timber. The inspector allowed three piles, only a few days from the woods, to be put in with the seasoned piles, and, after treatment it was proved by boring that the latter piles were well treated to the center and the former were penetrated by the oil about 1 in. only, and that that space was not very well saturated. This, of course, is an extreme case.

The writer has often observed that the oil can be injected into piles which have had only a week or two of seasoning much more rapidly than when the piles are put into the cylinder fresh from the stump, or are taken out of water storage.

Piles allowed to lie in the sun, on ground more or less wet, will not only show a different degree of seasoning on the upper and lower sides, but, after creosoting, will show very plainly a difference of saturation. This, no doubt, was the cause of the irregular treatment of the piles eaten by marine worms at the Pensacola Navy Yard. These piles were from West Pascagoula, and nearly all were delivered at the works by water. In hauling them out, for sorting

an order, while most of them were put on skids, some were allowed to lie on the wet ground without occasional turning. Mr. Bowser.

The relation between the cross-section and the cubic contents of timber gives large variation in the absorption. The absorptive power of a 12 by 12-in. stick, compared with a 1-in. plank, when the treatment would give about ½ in. of penetration, would be as 16 to 100.

In sticks of the same cross-section, the shorter ones will absorb more, on account of the penetrating power of the oil being greater in the ends of the fibers. In heavy treatments the oil will penetrate as much as 1 ft. into the end of heart wood if it is not very resinous, and it will sometimes penetrate 5 or 6 ft. into the ends of sticks of loblolly and old field pine.

No matter how carefully a charge is inspected, it is only possible to get an average treatment. The writer doubts that human ability can select from a promiscuous pile of round or square timber a cylinder load from which two or three or all the pieces could be weighed before and after treatment so as to give a basis of measurement for oil which would not often vary as much as 100% or more, from the actual quantity in the timber. Future investigation may show whether or not this doubt is correct.

Here is a case in point, where 80-ft. piles were gauged by 5-ft. test pieces: In the calculations for the quantity of oil to be injected into the piles, 12% additional was allowed for discrepancies in the measuring system. On account of the short pieces having a much greater proportion of end wood exposed than the piles, the result should have shown a greater quantity of oil than by the tank measurement, if the absorbing power of the different piles was approximately equal. The allowance for the inaccuracies of the measuring system would seem to be very close to what it should have been, and, no doubt, very nearly the correct quantity of oil to treat the timber properly passed from the measuring tank into the cylinder, but, according to the test pieces, 37½% of the oil was missing. From the construction of the plant, the oil must have gone either into the wood or into the underground dumping tank through leaking valves, and the only point to be settled is—which?

L. J. Le Conte, M. Am. Soc. C. E. (by letter).—The writer's experience in this matter has been confined to operations on the Pacific Coast, where the *modus operandi* is quite different, in many respects; but, nevertheless, so far as he is able to judge, the final results seem to be about the same as for the method reported by the author. Mr. Le Conte.

In 1890, when creosoting works were fairly started in California, the writer was classed among the stalwart advocates of this process of preserving timber. He was untiring in his efforts to reduce the

Mr. Le Conte.

uncertainties of the process to a minimum, and, with this end in view, studied carefully the minutest details of operations from the very beginning to the final taking out of the finished product. After the most thorough research he is free to state that the very best creosoting works in the country, using the very best grade of oil and performing the operations in the most thorough and conscientious manner cannot turn out a uniformly good product. That is to say, the general output of the works, figuratively speaking, may be classified as follows, according to the degrees of imperfection:

*First.*—One-quarter will be found, on examination, to be first-class in every particular, with no defects.

*Second.*—One-quarter will be slightly imperfect, but would easily pass inspection.

*Third.*—One-quarter will barely pass inspection.

*Fourth.*—One-quarter will not pass inspection at all, and would have to be put into the boiler for a second dose, or sold to some one who is not so particular. All four classes have had the same treatment, administered by the same competent men and at the same time, and yet the final results are widely different. There can be but one explanation for this unavoidable state of affairs, and that is, the natural variations in the physical character of the timber; nothing else will account for it. It is extremely difficult to cull out the inferior timber before preservation, and, as a rule, it is never done.

The natural variations can be brought out most graphically by taking a condemned pile, cutting it into 2-ft. lengths, and then critically examining the sections made by the saw. Many years ago, when the writer first looked at them, they threw a hopeless cloud of doubt about the efficiency of the entire process. Long experience, however, has toned down these unavoidable difficulties very materially, so that now if a uniformly good job is demanded the timber must be fresh cut green timber, free from physical defects, and selected with the greatest possible care. Even then, physical defects will crop out in spite of every precaution. In the hurry of every-day business, and especially when the superintendent of the works has a rush order, care in selection of material is simply out of the question; at all events, such care is never taken, disappointment is sure to follow in a few months, and the creosoting plant is given a black eye, so to speak.

In preparing specifications, there is just one thing to keep constantly in mind, and that is, one cannot, by any set of specifications, obtain a better product than the creosoting plant is physically able to produce. This is the business limit beyond which one cannot advance. Therefore, in preparing specifications, the first thing to find out is what the creosoting plant is physically able to do; then

the specifications should be framed so as to compel the works to comply with them. Mr. Le Conte.

In California the treatment is quite different from that described by the author, and a brief statement may be of interest.

The timber to be preserved is loaded on heavy iron trucks and run into the boiler, and then the ends are closed tight.

All the upper cocks are then closed and the three bottom cocks are opened and the vacuum pumps started. The hot creosote oil (130° fahr.) rises from the ground-tanks and gradually fills the boiler. The foreman watches the filling by feeling the rise of the hot line on the shell of the boiler until it is nearly full of hot oil. Then he stops the vacuum pumps, closes the three bottom cocks and opens a 2-in. safety cock on top of the boiler. He then completes the filling of the boiler with an auxiliary force pump and watches the filling until complete, by means of the safety cock.

When the boiler is full, superheated steam is turned into the steam coils, in the lower half of the boilers, the temperature of the contents being raised from 130° to 220° fahr., and maintained at that temperature for a period of about 10 hours. The vapors of sap and moisture from the timber are blown off through the safety cock on top of the boiler. As long as the sap vapors are rising and discharging the temperature is easily held at 220° fahr., but as soon as these vapors are all driven off, the temperature rises rapidly and the vapors of naphthalene begin to blow off, and, condensing, fall like snowflakes about the boiler room. Vaporization is finished. Auxiliary pumps are started once more and the boiler entirely filled.

All cocks of every description are now closed tight, and, for the first time since operations began, the pressure process begins. The measured quantity of oil, previously calculated, is then forced in with force pumps, the time required depending upon the character of the timber being treated, generally from 4 to 5 hours. The pumps keep up a steady pressure of 150 lb. per sq. in. on the boiler, and the steam coils below maintain a steady temperature of about 200° fahr. When the measured quantity is forced in, the process is completed.

The total time of treatment from beginning to end generally approximates 16 hours. The depth of penetration and quantity of dead oil are the main features. On the Pacific Coast the specifications generally call for 12 to 14 lb. per cu. ft. The writer prefers heavier doses; and, furthermore, that the penetration of the black oil shall not be less than 1 in. in depth. This requirement arises from the fact that the oil, while being forced into the timber by pressure, undergoes a mechanical separation, the lighter and more fluid tar-acids and naphthalene penetrate through the full depth of the sap wood, while the heavier portions, mostly the residuum, remain near

Mr. Le Conte. the surface. It is the latter which, to his mind, constitutes the main protection against the teredo.

The author refers to the danger of the dilution of oil with from 19 to 24% of water. This danger could hardly arise in the California process, in which the green timber is boiled in oil at 220° fahr. for 10 hours at a stretch, or until all watery vapors disappear. This is the highest temperature to which the timber is subjected at any time. The author's suggestion that the weight of creosote due to impregnation is more reliable than the volumetric tank method now in vogue would hardly be practicable in the California practice.

The author's experience at Pensacola, where only 5 piles out of 198 were badly worm-eaten after 15 months' exposure, seems to the writer to be a very fair record, indeed.

# MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

## WILLIAM MARSHALL REES, M. Am. Soc. C. E.*

DIED DECEMBER 4TH, 1905.

William Marshall Rees was born at Stroudsburg, Pennsylvania, on December 24th, 1851, and died at Memphis, Tennessee, on December 4th, 1905.

He was graduated from Lehigh University in 1874 at the head of his class. Almost immediately after graduation Mr. Rees went with the East Sugar Loaf Colliery, of Stockton, Pennsylvania, as Assistant Superintendent and Engineer, and remained with them in that capacity until July, 1875, when he left to accept the position of Superintendent of the Humboldt Colliery at Hazleton, Pennsylvania.

In January, 1877, he left Hazleton, to engage in railroad and mining work. During 1877-78 he located and constructed the Stroudsburg and Bethlehem Railroad. During the same time he was Mining Engineer for G. B. Linderman and General Manager of the Bethlehem Iron Company.

In December, 1878, Mr. Rees left his native State to go south and engage in Government work on the Mississippi River under the Mississippi River Commission, being attracted by the high scientific character of the work.

During the first three years of his Government service, he was engaged on surveys, examinations, gauging the river and gathering other data on which to base plans for its improvement. During 1881 he was engaged in constructing snagboats to be operated on Red River. In 1882 he went with the Pratt Coal and Coke Company, of Birmingham, Alabama, as Superintendent. In 1883 he returned to the Government service on the Mississippi River and, as Principal Assistant Engineer, had charge of all channel work in the First and Second Districts. During his Government service he designed and constructed various floating plants used in connection with channel improvement.

In the latter part of 1889 Mr. Rees went with the Sanitary District of Chicago as Assistant Chief Engineer. Upon the resignation of the Chief Engineer, L. E. Cooley, M. Am. Soc. C. E., Mr. Rees also resigned. He then returned to his old position in the Govern-

* Memoir prepared by W. M. Gardner, M. Am. Soc. C. E.

ment service, where he remained until his death, the result of injuries received in the performance of duty.

During his different engagements Mr. Rees did a good deal of expert work, being eagerly sought by those desiring such advice, which he was eminently fitted to give. He was a man of broad education, and possessed a wonderful fund of information in all branches of the profession, which he was ever ready to impart to the younger members.

It has been the writer's good fortune to be associated with Mr. Rees for the past ten years, and he feels himself indebted to him for many kindnesses received from the helping hand so generously extended to smooth over rough places.

Mr. Rees was a Charter Member and Past-President of the Memphis Engineering Society. He was elected a Member of the American Society of Civil Engineers on October 4th, 1905.

# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

OF

# CIVIL ENGINEERS.

(INSTITUTED 1852.)

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VOL. XXXII. No. 2.

FEBRUARY, 1906.

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NEW YORK 1906.

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# American Society of Civil Engineers.

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E. KUICHLING.

*Term expires January, 1908:*
ONWARD BATES,
BERNARD R. GREEN.

*Secretary*, CHARLES WARREN HUNT.

*Treasurer*, JOSEPH M. KNAP.

*Directors.*

| *Term expires January, 1907:* | *Term expires January, 1908:* | *Term expires January, 1909.* |
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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER: - - - - 533 Columbus.
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INSTITUTED 1852.

# PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

### FIFTY-THIRD ANNUAL MEETING.*

**January 17th, 1906.**—The meeting was called to order at 10 A. M.; President C. C. Schneider in the chair, T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, about 350 members.

The reading of the minutes of the meeting of January 3d was dispensed with.

Messrs. W. D. Kelley, George L. Wilson and J. A. Knighton were appointed tellers to canvass the Ballot for Officers for the ensuing year.

* A full report of the Fifty-third Annual Meeting is printed on pages 49 to 84 of this number of *Proceedings*.

The Annual Report of the Board of Direction and the Annual Reports of the Secretary and of the Treasurer,* for the year ending December 31st, 1905, were presented, and, on motion, duly seconded, accepted and placed on file.

A progress report,† from the Special Committee on Uniform Tests of Cement, was presented by Richard L. Humphrey, M. Am. Soc. C. E., Secretary of that Committee.

On motion, duly seconded, the report was received, placed on file, and the Committee continued.

A majority report, and also minority reports,‡ from the Special Committee on Rail Sections, were presented by Robert W. Hunt, M. Am. Soc. C. E., Secretary of that Committee.

On motion, duly seconded, the report was received, placed on file, and the Committee continued.

A progress report,§ from the Special Committee on Concrete and Reinforced Concrete, was presented by Richard L. Humphrey, Secretary of that Committee.

On motion, duly seconded, the report was received, placed on file, and the Committee continued.

The following proposed amendments to the Constitution were then considered:

Amend Article II, Section 2, as follows:

Insert after the word "Civil" in the first line "Engineer who shall have reached a position of recognized standing in the profession, in its several branches including." Also strike out all of the second line beginning with the word "Electrical," and insert "and Electrical Engineering or in Architecture or Marine Architecture." Also strike out all after the word "age" in the fourth line.

The section will then read:

"2. A Member shall be a Civil Engineer who shall have reached a position of recognized standing in the profession, in its several branches, including Military, Naval, Mining, Mechanical and Electrical Engineering, or in Architecture or Marine Architecture. He shall be at the time of admission to membership not less than thirty years of age."

This amendment was proposed by Messrs. James Owen, Ralph H. Chambers, Philip W. Henry, Walter H. Sears, S. Whinery, A. P. Boller and Foster Crowell.

The Assistant Secretary read letters relating to this amendment from Messrs. Charles H. Ledlie, L. S. Randolph, Dugald C. Jackson, Benjamin Thompson, Edward M. Boggs, Ellis B. Noyes, Joseph Lillich, A. B. Wood, Robert L. Lund and Mark L. Ireland.

* The Annual Reports of the Board of Direction, the Secretary and the Treasurer may be found on pages 7 to 18 of the *Proceedings* for January, 1906 (Vol. XXXII.)

† See page 49.

‡ See page 50.

§ See page 64.

S. Whinery, M. Am. Soc. C. E., presented the following motion:

"That the amendments be referred to a committee of five Corporate Members, to be appointed by the President, which committee shall report to the next Annual Convention what, if any, changes they deem advisable in the present classification of the membership of the Society, or in the qualifications for each grade of membership; and submit any amendments to these amendments which they may recommend."

This motion was seconded by Foster Crowell, M. Am. Soc. C. E.

E. P. North, M. Am. Soc. C. E., moved in amendment that the five Corporate Members mentioned in the motion be increased by one Associate and one Junior, which amendment was accepted.

The motion was then put to vote and carried unanimously.

The following were appointed members of the Nominating Committee to serve two years:

| | | | | |
|---|---|---|---|---|
| JOHN H. COOK..... | *Representing* | *District* | *No.* | *1.* |
| LEONARD METCALF..... | " | " | " | *2.* |
| A. H. SUTERMEISTER..... | " | " | " | *3.* |
| EDGAR MARBURG..... | " | " | " | *4.* |
| JOHN W. ALVORD..... | " | " | " | *5.* |
| A. H. ZELLER..... | " | " | " | *6.* |
| FRANK O. MARVIN..... | " | " | " | *7.* |

The Assistant Secretary reported that the Board of Direction had awarded the prizes for the year ending with the month of July, 1905, in accordance with the recommendations of the Committee appointed for that purpose, as follows:

That the Norman Medal be awarded to Paper No. 997, "The Structural Design of Buildings," by C. C. Schneider, President, Am. Soc. C. E.

That the Thomas Fitch Rowland Prize be awarded to Paper No. 981, "Lake Cheesman Dam and Reservoir," by Charles L. Harrison, M. Am. Soc. C. E., and Silas H. Woodard, Assoc. M. Am. Soc. C. E. (now M. Am. Soc. C. E.).

That the Collingwood Prize be awarded to Paper No. 983, "Lateral Earth Pressures and Related Phenomena," by E. P. Goodrich, Jun. Am. Soc. C. E. (now M. Am. Soc. C. E.).

The Assistant Secretary announced that the Thirty-eighth Annual Convention would be held at The Hotel Frontenac, Thousand Islands, New York, on June 26th to 29th, 1906.

The Assistant Secretary announced the death of Francis Edward Snyder, elected Member, September 6th, 1905; died December 23d, 1905.

The report of the tellers* appointed to canvass the Ballots for Officers for the ensuing year was presented.

* See page 73.

The President announced the election of the following officers:

*President, to serve one year:*

FREDERIC P. STEARNS, Boston, Mass.

*Vice-Presidents, to serve two years:*

ONWARD BATES, Chicago, Ill.
BERNARD R. GREEN, Washington, D. C.

*Treasurer, to serve one year:*

JOSEPH M. KNAP, New York City.

*Directors, to serve three years:*

GEORGE GIBBS, New York City.
J. WALDO SMITH, New York City.
EMIL SWENSSON, Pittsburg, Pa.
JAMES M. JOHNSON, Louisville, Ky.
WYNKOOP KIERSTED, Kansas City, Mo.
WILLIAM B. STOREY, JR., Topeka, Kans.

Mr. Green and Mr. Swensson conducted Mr. Stearns, the President-elect, to the chair.

Mr. Stearns addressed the meeting briefly.

Adjourned.

**February 7th, 1906.**—The meeting was called to order at 8.35 P. M.; President Frederic P. Stearns in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 109 members and 26 guests.

The minutes of the meeting of January 3d, 1906, were approved as printed in the *Proceedings* for January, 1906.

A paper, entitled "Test of a Three-Stage, Direct-Connected Centrifugal Pumping Unit," by Philip E. Harroun, M. Am. Soc. C. E., was presented by the Assistant Secretary, who also read a written communication on the subject from Elmo G. Harris, M. Am. Soc. C. E. The paper was discussed further by H. F. Dunham, M. Am. Soc. C. E.

Ballots for membership were canvassed, and the following candidates elected:

AS MEMBERS.

GEORGE GRAY ANDERSON, Denver, Colo.
WALTER FRANCIS BALLINGER, Philadelphia, Pa.
SVERRE DAHM, New York City.

GEORGE TILLINGHAST HAMMOND, New York City.
JOHN FARNSWORTH HAMMOND, New York City.
WILLIAM HUGGINS, Sao Paulo, Brazil.
ANDREW MURRAY HUNT, San Francisco, Cal.
WILLIAM HENRY HUNTER, Manchester, England.
LUIGI LUIGGI, Rome, Italy.
WILLIAM EDWIN MOORE, Clarkston, Wash.
WILLIAM MUESER, New York City.
HENRY IRWIN RANDALL, Berkeley, Cal.

AS ASSOCIATE MEMBERS.

JAMES RAY AIKENHEAD, East Liverpool, Ohio.
DE WITT DUKES BARLOW, Cape May City, N. J.
LORENZO DANA CORNISH, Beaver, Pa.
GEORGE WASHINGTON CRAIG, Omaha, Nebr.
FREDERICK WILLIAM DENCER, Chicago, Ill.
FRANKLIN EDWARD ESTES, Rincon Antonio, Oaxaca, Mexico.
MAURICE GOLDENBERG, Detroit, Mich.
EDMUND RYOND HALSEY, Newark, N. J.
HARRY GARFIELD HARRINGTON, New York City.
GEORGE ROGERS HECKLE, Columbus, Ohio.
HENRY DETRICK JOUETT, New York City.
JOHN EDWARD KIRKHAM, Ambridge, Pa.
EGBERT JESSUP MOORE, New York City.
ARTHUR TAPPAN NORTH, Chicago, Ill.
CHIKAO OINOUYE, Steelton, Pa.
ALBERT HENRY PERKINS, Chinook, Mont.
JOHN RICHARDS PILL, Carbon Hill, Ala.
PAUL AUGUST SCHUCHART, New York City.
WILLARD WILBERFORCE STONE, Syracuse, N. Y.
FRANK HAMANT TROW, Clinton, Mass.
EARLE HUBBEL WELLES, Cleveland, Ohio.
EZRA BAILEY WHITMAN, New York City.
SAMUEL WALTER WILLIAMS, New York City.
CHARLES SUMNER WILLIAMSON, Pittsburg, Pa.

AS ASSOCIATES.

COLEMAN MERIWETHER, New York City.
ALBERT MOYER, New York City.
JOHN MCGAW WOODBURY, New York City.

The Assistant Secretary announced the transfer of the following candidates, by the Board of Direction, on February 6th, 1906:

FROM ASSOCIATE MEMBER TO MEMBER.

RICARDO MANUEL ARANGO, Panama, Panama.
GEORGE THOMAS BARNSLEY, Pittsburg, Pa.
EDWARD FRANCIS HAAS, San Francisco, Cal.
EUGENE LENTILHON, New York City.
FRED WILLIAM LEPPER, Cleveland, Ohio.
AMOS SCHAEFFER, New York City.

The election of the following candidates, by the Board of Direction:

AS JUNIORS.

On September 5th, 1905:

FRANK C. HUNTSMAN, Macon, Mo.

On December 5th, 1905:

LEON LINCOLN GAY, Minidoka, Idaho.

On January 2d, 1906:

FRANCIS WINFIELD COLLINS, New York City.
CHARLES HOUCHIN HIGGINS, Jersey City, N. J.
HAROLD SCOTT LOUGHRAN, New Rochelle, N. Y.
ALFRED MARSHALL WYMAN, East Orange, N. J.

On February 6th, 1906:

LEWIS PAUL BREMER, New Rochelle, N. Y.
ELMER GEORGE BRUA, Monterey, Cal.
FRANCIS STIRLING CROWELL, Flushing, N. Y.
WILLIAM EARLE ELAM, Empire, Canal Zone, Panama.
FRITZ LOUIS METZGER, Freedom, Pa.
KENNETH DUNHAM OWEN, Montclair, N. J.
LIONEL HENRY PEABODY, JR., Providence, R. I.
LAFAYETTE CLOWE REYNOLDS, Mt. Vernon, N. Y.
ALBERT IRVINE STILES, Lima, Peru.
MORITZ WORMSER, New York City.

The Assistant Secretary announced the following deaths:

CARL CHRISTIAN ADOLPH BOTH, elected Member, September 2d, 1891; died January 12th, 1906.

JOSEPH HOCKMAN BOWMAN, elected Associate Member, December 2d, 1903; date of death unknown.

Adjourned.

**February 14th, 1906. Extra Meeting.**—The meeting was called to order at 8.40 P. M.; Vice-President Kuichling in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 65 members and 20 guests.

A lecture, entitled "Telephone Line Engineering," was presented by C. J. H. Woodbury, M. Am. Soc. C. E., and illustrated with lantern slides.

A vote of thanks to Mr. Woodbury for his interesting lecture was passed unanimously.

**February 21st, 1906.**—The meeting was called to order at 8.40 P. M., Charles S. Gowen, Director, in the chair; F. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 103 members and 31 guests.

A paper by John S. Sewell, M. Am. Soc. C. E., entitled "The Economical Design of Reinforced Concrete Floor Systems for Fire-Resisting Structures," was presented by the author.

The paper was discussed orally by Messrs. E. P. Goodrich, J. Kahn and H. T. Forchhammer, and illustrated with lantern slides.

Adjourned.

## OF THE BOARD OF DIRECTION.

(Abstract.)

**January 2d, 1906.**—President Schneider in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bissell, Bowman, Craven, Croes, Curtis, Gowen, Knap, N. P. Lewis, and Osgood.

Action was taken in regard to members in arrears for dues.

The following report was received from the Committee on Award of Prizes:

"PHILADELPHIA, PA., DEC. 26TH, 1905.

*"To the Board of Direction,*
AMERICAN SOCIETY, CIVIL ENGINEERS,
NEW YORK.

"GENTLEMEN:—Your Committee appointed for the purpose, recommend the award of prizes for papers published during the year ending July 1st, 1905, as follows:

"The Norman Medal to Mr. C. C. Schneider, for Paper No. 997, 'The Structural Design of Buildings.'

"The Thomas Fitch Rowland Prize to Messrs. Charles L. Harrison and Silas H. Woodard, for Paper No. 981, 'Lake Cheesman Dam and Reservoir.'

"The Collingwood Prize for Juniors to Mr. E. P. Goodrich, for Paper No. 983, 'Lateral Earth Pressures and Related Phenomena.'

"JAMES CHRISTIE,
"J. T. FANNING,
"F. C. KUNZ,
*"Committee."*

The Norman Medal, The Thomas Fitch Rowland Prize, and the Collingwood Prize for Juniors were awarded in accordance with the recommendations of the foregoing report.

The following resignations were accepted as taking effect December 31st, 1905:

MEMBERS:
ERNESTO J. BALBIN,
ALFRED WILLARD FRENCH.

ASSOCIATE MEMBERS:
GEORGE H. CRAFTS,
RALPH PEVERLEY,
EDMUND P. RAMSEY.

Applications were considered and other routine business transacted.

Two Associate Members were transferred to the grade of Member, and thirteen candidates for Junior were elected.

**Adjourned.**

**January 17th, 1906.**—The Board met during the Annual Meeting, as required by the Constitution, President Frederic P. Stearns in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, Messrs. Bissell, Bowman, Ellis, Fisher, Gowen, Green, Lewis, Noble, Schneider, Sherrerd, Smith, and Swensson.

The following Standing Committees were appointed:

Finance Committee: Emil Kuichling, Charles S. Gowen, George Gibbs, M. L. Holman, George S. Pierson.

Publication Committee: Morris R. Sherrerd, J. Waldo Smith, Onward Bates, Bernard R. Green, George S. Webster.

Library Committee: Nelson P. Lewis, A. L. Bowman, Ralph Modjeski, H. Bissell, Chas. Warren Hunt.

A Committee on Membership was also appointed.

A letter-ballot was ordered for the election of a Secretary for the ensuing year.

Frederic P. Stearns, President, Am. Soc. C. E., was selected from the membership of the Society as a Member of the John Fritz Medal Board of Award.

Adjourned.

**February 6th, 1906.**—8.40 P. M.—President Stearns in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, Messrs. Bissell, Bowman, Ellis, Gibbs, Gowen, Knap, Kuichling, Lewis, Noble, Schneider, and Smith.

Ballots for the election of a Secretary were canvassed, and Chas. Warren Hunt, having received 29 votes, was declared elected.

In compliance with the action of the Annual Meeting, the following Committee on Amendments to the Constitution was appointed by the President: Messrs. Samuel Whinery, Alfred Noble, Onward Bates, Morris R. Sherrerd, and Samuel E. Tinkham, representing the Corporate Members; John C. Trautwine, Jr., representing the Associates, and Thaddeus Merriman, representing the Juniors.

The following resolutions were adopted unanimously:

"*Resolved,* That the thanks of the American Society of Civil Engineers be extended to the Commandant and Officers attached to the New York Navy Yard for their kindness and courtesy in receiving the members of this Society at the Yard, and permitting the inspection of the various buildings, dry docks, etc., the U. S. Battleship *Connecticut,* and other interesting and instructive features."

"*Resolved,* That the thanks of the American Society of Civil Engineers be extended to Gen. Howard Carroll and to the Hon. John H. Starin for their great kindness and courtesy in placing at

the disposal of the Society the steamer *Valley Girl* on the occasion of the Annual Meeting, January 18th, 1906, which enabled a large party of members of the Society to make a very pleasant excursion to the New York Navy Yard and other points of interest."

Applications were considered and other routine business transacted.

Six Associate Members were transferred to the grade of Member, and ten candidates were elected Juniors.

Adjourned.

## REPORT IN FULL OF THE FIFTY-THIRD ANNUAL MEETING, JANUARY 17th AND 18th, 1906.

**Wednesday, January 17th, 1906.**—The meeting was called to order at 10 A. M.; President C. C. Schneider in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, about 350 members. Meeting called to Order.

THE PRESIDENT.—The meeting will please come to order. The minutes of January 3d, 1906, in accordance with the custom, will be printed in the January number of *Proceedings*, and come up in due course for action at the meeting of February 7th, 1906. In view of this fact, the reading of the minutes will be dispensed with, unless some call is made for them.

The Chair appoints the following gentlemen as tellers to canvass the Ballots for Officers to be elected at this meeting: Messrs. W. D. Kelley, George L. Wilson and J. A. Knighton. The ballot does not close until twelve o'clock, noon, but to enable a report to be made as soon as possible after that time, the tellers will please proceed with their duty at once. Ballots will be received until twelve o'clock. At that hour the ballot will be declared closed. Tellers Appointed.

The next order of business is the report of the Board of Direction. Report of the Board of Direction.

The Assistant Secretary read the report of the Board of Direction.*

THE PRESIDENT.—The report of the Secretary.†

The Assistant Secretary read the report of the Secretary.

THE PRESIDENT.—The report of the Treasurer will be read by Mr. Knap.

The Treasurer read his report.‡

THE PRESIDENT.—Gentlemen, you have heard the reports of the Board of Direction, the Secretary, and the Treasurer, and if there is no objection to them they will be received and placed on file.

On motion, duly seconded, the reports of the Board of Direction, the Secretary, and the Treasurer were received and placed on file.

THE PRESIDENT.—The report of the Special Committee on Uniform Tests of Cement, by Mr. George S. Webster, Chairman. Report of the Cement Committee.

RICHARD L. HUMPHREY, M. Am. Soc. C. E.—Mr. Webster, the Chairman of the Committee is unable to be present to-day, and I, as Secretary, have been asked to read the report, which is very brief.

JANUARY 17TH, 1906.

*To the President and Members,*

AMERICAN SOCIETY OF CIVIL ENGINEERS.

GENTLEMEN:

The investigations in progress have not advanced sufficiently to reach definite conclusions, and your Special Committee on Uniform

* See *Proceedings*, Vol. XXXII, p. 7 (January, 1906).
† See *Proceedings*, Vol. XXXII, p. 16 (January, 1906).
‡ See *Proceedings*, Vol. XXXII, p. 15 (January, 1906).

Report of the Cement Committee (continued).

Tests of Cement is unable to present a final report at this time, and it asks, therefore, that it be continued.

G. S. WEBSTER,
*Chairman;*
RICHARD L. HUMPHREY,
*Secretary.*

*Committee:*
GEORGE S. WEBSTER,
RICHARD L. HUMPHREY,
GEORGE F. SWAIN,
ALFRED NOBLE,
LOUIS C. SABIN,
SPENCER B. NEWBERRY,
CLIFFORD RICHARDSON,
F. H. LEWIS,
W. B. W. HOWE.

THE PRESIDENT.—Gentlemen, you have heard the report of the Special Committee on Uniform Tests of Cement. What action do you want taken in regard to it?

It was moved and seconded that the report be received and the Committee be continued.

The motion was carried.

Report of the Committee on Rail Sections.

THE PRESIDENT.—The report of the Special Committee on Rail Sections.

ROBERT W. HUNT, M. Am. Soc. C. E., Secretary of the Special Committee on Rail Sections.—May I request that the Secretary read that report? I am not sure whether or not the Chairman is here.

The report of the Special Committee on Rail Sections was read by the Assistant Secretary, as follows:

## REPORT OF THE SPECIAL COMMITTEE ON RAIL SECTIONS.

*To the American Society of Civil Engineers,*

GENTLEMEN:

Your Special Committee on Rail Sections respectfully report that the instructions under which they were appointed in 1902 are:

*1.*—To report upon the results obtained in the use of rails of the sections presented to the Society in Annual Convention, August 2d, 1893, by a special committee appointed for that purpose;

*2.*—To report whether any modification of any of said sections is advisable, and, if so, to recommend such modification;

*3.*—To report upon the recognized practice as to chemical composition and mechanical treatment used in the manufacture of rails, and the manner of inspection of the same;

*4.*—To report upon the advisability of the establishment of a

form of specification covering the manufacture and inspection of rails;

*5.*—If found advisable, to recommend a form of specification for the manufacture and inspection of rails.

Since their appointment, they have held as many meetings as the progress of their work seemed to require; in addition to which, and, in fact, in pursuance of the action of the Committee at those meetings, extensive correspondence has been carried on by the officers of the Committee with the officials of the principal railroads of the United States, Canada, and Mexico. There has also been correspondence with the officers of the Rail Committee of the American Railway Engineering and Maintenance of Way Association, and one joint meeting held with that Committee. There have also been two meetings with a Committee representing the Steel Rail Manufacturers of the United States.

Your Committee would now report:

*1.—To report upon the results obtained in the use of rails of the sections presented to the Society in Annual Convention, August 2d, 1893, by a special committee appointed for that purpose:*

During 1905 reports have been received from 79 of the leading railroads of the United States, Canada and Mexico.

13 roads had no criticism to make for or against the American Society Sections.

23 roads say they are entirely satisfactory.

2 say emphatically they are good standards.

14 roads criticized the shape of head.

2 roads criticized the web.

2 roads say it ought to have a broader base.

Some other criticisms refer to the vertical sides, which, they claim, wear the wheel flanges, and some other slight changes in shape are suggested.

48 railroads reported that the Society's sections were their standard.

10 railroads reported that they did not use them.

19 railroads have used them partially as standard.

3 railroads have used them, but do not now.

63 railroads say positively they intend to use them as standard.

14 say they will not do so.

2 say they will probably use them.

*2.—To report whether any modification of any of said sections is advisable, and, if so, to recommend such modification:*

What are popularly known as the rail sections of this Society were recommended by a special Committee in 1893. For the year ending June 30th, 1905, the following percentage of their total out-

Report of the Committee on Rail Sections (continued).

put was rolled by eight mills in the United States for domestic and export uses:

| | Domestic. | Foreign. |
|---|---|---|
| Pennsylvania Steel Co..... | 82% | Practically none. |
| Maryland Steel Co..... | | |
| Cambria Steel Co..... | 77% | None. |
| Illinois Steel Co..... | 84% | None. |
| Carnegie Steel Co..... | 69.34% | 78.9% |
| Lackawanna Steel Co..... | 99.3% | Practically none. |
| Tennessee Coal & Iron Co.. | 88.6% | None. |
| Colorado Fuel & Iron Co... | 65% | None. |

Since 1893 the speed of trains, and wheel loads, have been increased proportionately very much more than the weight of rails. The increase in driving-wheel loads is approximately 60%, while the maximum weight of rails has increased from 80 to 100 lb., or 25 per cent.

Rails of the heavier sections are not giving the service expected of them, even after making due allowance for the increased traffic tonnage or for the trouble caused by badly balanced driving wheels, and poor condition of rolling stock and roadbed, but, after due consideration of all the information collected, your Committee does not feel justified in now recommending any modifications of the sections.

*3.—To report upon the recognized practice as to chemical composition and mechanical treatment used in the manufacture of rails, and the manner of inspection of the same:*

In relation to the chemical composition of rails made by the acid Bessemer process, the general practice in the United States is to accept what are known as the Manufacturers' Standard Specifications. These are:

| | 70 lb. up to 80 lb. | 80 lb. up to 90 lb. | 90 lb. up to 100 lb. |
|---|---|---|---|
| Carbon ..... | 0.45 to 0.55 | 0.48 to 0.58 | 0.50 to 0.60 |
| Phosphorus, not over. | 0.10 | 0.10 | 0.10 |
| Silicon, not over..... | 0.20 | 0.20 | 0.20 |
| Manganese ..... | 0.75 to 1.00 | 0.80 to 1.10 | 0.80 to 1.10 |

Previous to December 10th, 1904, the carbon percentages were five points lower, the other elements being amounts as now. Some railroads have insisted and obtained modifications by which the carbon percentages have been increased and the phosphorus kept not to exceed 0.085 per cent. In a few instances, phosphorus has been held lower, but such rails are now made only from a large admixture of imported ores. Some of the Canadian roads have been able to obtain, from the United States rail makers, 80-lb. American Society section rails with the following actual composition:

| | |
|---|---|
| Carbon ..... | 0.58 to 0.64, average 0.60 |
| Phosphorus ..... | 0.059 to 0.071 |
| Silicon ..... | 0.125 to 0.165 |
| Sulphur ..... | 0.049 to 0.056 |
| Manganese ..... | 0.93 to 0.96 |

The Bessemer rails, which the same parties are having manufactured in Canada, contain:

| | |
|---|---|
| Carbon ..... | 0.53 to 0.63, average 0.58 |
| Phosphorus, not to exceed | 0.085 |
| Silicon ..... | 0.075 to 0.15 |
| Sulphur, not to exceed.. | 0.075 |
| Manganese ..... | 0.80 to 1.10 |

Up to the present time, it has not been proven that the Basic Bessemer process of rail making is commercially practical with American iron ores. The Basic Open-Hearth process has reached enormous development in the United States, but only one plant is regularly putting its steel into rails. Their standard specifications are:

| | 70 lb. up to 80 lb. | 80 lb. up to 90 lb. | 90 lb. up to 100 lb. |
|---|---|---|---|
| Carbon ..... | 0.50 to 0.60 | 0.55 to 0.65 | 0.58 to 0.68 |
| Phosphorus, not over. | 0.06 | 0.06 | 0.06 |
| Silicon, not over..... | 0.20 | 0.20 | 0.20 |
| Manganese ..... | 0.75 to 1.05 | 0.80 to 1.10 | 0.80 to 1.10 |

There is also a Basic Open-Hearth rail mill in Canada.

The mechanical treatment of the metal differs somewhat in the practice of the largest American rail producers. At three mills the bloom is reheated after leaving the blooming rolls, and before entering the rail rolls. At the others, the rolling process is a continuous one, from the time the ingots are drawn from the heating furnaces. All but two of the mills have three-high trains of rail rolls. During several years, all the mills have been crowded with work, and the tendency has been to use every exertion to increase production. In your Committee's opinion, this has led to rolling the steel at too rapid a reduction and at too high a temperature, and to other details which largely account for the unsatisfactory service given by the heavy-sectioned rails.

Practically all large purchasers of rails have them inspected at the mills either by men detailed from their own organization or by professional inspectors. Such inspection covers seeing that the provisions of the specifications under which the rails have been purchased are observed; particularly checking the accuracy of section, squareness and length of sawing, accuracy of drilling, straightness in line and surface, and freedom from mechanical defects.

Report of the Committee on Rail Sections (continued).

*4.—To report upon the advisability of the establishment of a form of specification covering the manufacture and inspection of rails:*

In this country rails are made by two processes—Acid Bessemer and Basic Open Hearth—the former process covering quite 90% of the production. On the continent of Europe nearly all rails are made by the Basic Bessemer, and in England, with the exception of one works, all commercial rails are made by the Acid Bessemer process, the difference in the practice of the several countries being occasioned by the character of their available iron ores. The same controlling influence must be recognized in preparing chemical and other specifications for the manufacture of rails in this country. Your Committee believe that a low percentage of phosphorus and high percentage of carbon make a better rail steel than when the amount of the former element necessitates the curtailment of the latter. When rails of lighter sections were used, chemical conditions were not so important as with the heavier ones; this, because the rolling down of the steel to the smaller sections of necessity gave it more work, and also finished the rail at a lower temperature; thus producing a finer-grained and tougher metal. This partially explains why so many of the early steel rails gave good physical results, while their chemical composition was so irregular.

Taking everything into consideration, your Committee think it advisable to present specifications covering the manufacture and inspection of rails, but realize that restraining commercial ore conditions keep them from being ideal ones, chemically; and existing manufacturing plants and practice limit what can be specified for the physical treatment of the steel; but, believing, as your Committee do, that the physical treatment is of as great importance as the chemical composition, they do recommend certain requirements which should be enforced. These will tend toward the production of better wearing rails, and also safer ones. Your Committee recognize that commercial conditions cannot be entirely disregarded by engineers, but, at the same time, they believe that when it is known that existing practice results in danger to human life and limb, it becomes the duty of the engineer to insist on their being changed, even though that necessitates either a greater cost to the consumer or a somewhat less profit to the producer. That point will adjust itself, but the safer practice should be demanded. This view controlled your Committee in framing the clause of these recommended specifications governing the shearing of the rail blooms, as it is well known that one of the frequent causes of failure of steel rails is due to piping, and that this comes from unsound ingots. Unfortunately, such failures often cause accidents which result in large material damage, and, what is worse, the loss of life. Frequently,

such interior defects cannot be detected until after the rails have been subjected to traffic, hence it is of the greatest importance that care should be exercised in the manufacture with a view of reducing the danger to a minimum.

Your Committee have studied the results obtained from Basic Open-Hearth steel rails, and, while their use has not extended over many years, at the same time, the evidence points to their giving better service than the Bessemer rails. This is strikingly demonstrated by certain experimental very high carbon rails laid on the lines of the Pennsylvania Railroad. It must be understood that the physical differences of the two steels are not entirely due to their chemical composition; as it is a well-known metallurgical fact that steel made by the Basic Open-Hearth process possesses characteristics of its own.

They have prepared specifications for both Bessemer and Basic Open-Hearth rails. While the majority of the rail plants of the country are not now adapted to the making of Basic Open-Hearth rails, the greater known amount of the iron ore supply is suitable, hence the production of that kind of steel rails will increase.

*5.—If found advisable, to recommend a form of specification for the manufacture and inspection of rails:*

RECOMMENDED SPECIFICATIONS FOR BESSEMER STEEL RAILS.

*Process of Manufacture.*—The entire process of manufacture and testing shall be in accordance with the best state of the art, and the following instructions shall be faithfully executed:

Ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled, or until the metal in the interior has had time to solidify.

No bled ingots shall be used.

There shall be sheared from the end of the blooms formed from the top of the ingots, assuming that such blooms are about 8 by 8 in. square, at least 40 in., and if, from any cause, the steel does not then appear to be solid, the shearing shall continue until it does. If, by the use of any improvements in the process of making ingots, the defect known as piping shall be prevented, the above shearing requirements may be modified.

The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws, for a 33-ft. rail of 100-lb. section, of $6\frac{7}{16}$ in., and $\frac{1}{16}$ in. less for each 5-lb. decrease of section. These allowances to be decreased at the rate of $\frac{1}{90}$ in. for each second of time elapsed between the rail leaving the finishing rolls and being sawn. No artificial means of

Report of the Committee on Rail Sections (continued).

cooling the steel shall be used after the rails leave the rolls, nor shall they be held before sawing for the purpose of reducing their temperature.

*Chemical Composition.*—Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

| | 70 to 79 lb. Percentage. | 80 to 89 lb. Percentage. | 90 to 100 lb. Percentage. |
|---|---|---|---|
| Carbon | 0.50 to 0.60 | 0.53 to 0.63 | 0.55 to 0.65 |
| Phosphorus shall not exceed | 0.085 | 0.085 | 0.085 |
| Silicon " " " | 0.20 | 0.20 | 0.20 |
| Sulphur " " " | 0.075 | 0.075 | 0.075 |
| Manganese | 0.75 to 1.00 | 0.80 to 1.05 | 0.80 to 1.05 |

*Drop Test.*—One drop test shall be made on a piece of rail, not less than 4 ft. and not more than 6 ft. long, selected from each blow of steel. The test piece shall be taken from the top of the ingot. The rails shall be placed head upward on the supports, and the various sections shall be subjected to the following impact tests under a free falling weight:

| | |
|---|---|
| 70 to 79-lb. rails | 18 ft. |
| 80 to 89-lb. rails | 20 " |
| 90 to 100-lb. rails | 22 " |

If any rail breaks, when subjected to the drop test, two additional tests may be made of other rails from the same blow of steel, also taken from the top of the ingots, and if either of these latter rails fail, all the rails of the blow which they represent will be rejected, but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted.

The drop-testing machine shall have a tup of 2 000 lb. weight, the striking face of which shall have a radius of not more than 5 in., and the test rail shall be placed head upward on solid supports 3 ft. apart. The anvil block shall weigh at least 20 000 lb., and the supports shall be part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the test was made.

*Section.*—Unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with the paragraph relative to specified weight. A variation in height of $\frac{1}{64}$ in. less, or $\frac{1}{32}$ in. greater than the specified height, and $\frac{1}{16}$ in. in width will be permitted. The section of rail shall conform to the finishing dimensions.

*Weight.*—The weight of the rails will be maintained as nearly as possible, after complying with the preceding paragraph, to that specified in contract. A variation of one-half of 1% for an entire order will be allowed. Rails will be accepted and paid for according to actual weights.

*Length.*—The standard length of rails shall be 33 ft. Ten per cent. of the entire order will be accepted in shorter lengths, varying by even feet to 27 ft., and all No. 1 rails less than 33 ft. long shall be painted green on the ends. A variation of $\frac{1}{4}$ in. in length from that specified will be allowed.

*Drilling.*—Circular holes for splice-bars shall be drilled in accordance with the specifications of the purchaser. The holes shall conform accurately to the drawing and dimensions furnished, in every respect, and must be free from burrs.

*Straightening.*—Care must be taken in hot-straightening the rails, and it must result in their being left in such a condition that they shall not vary throughout their entire length more than 5 in. from a straight line in any direction, when delivered to the cold-straightening presses. Those which vary beyond that amount, or have short kinks, shall be classed as second-quality rails and be so stamped.

Rails shall be straight in line and surface when finished—the straightening being done while cold—smooth on head, sawed square at ends, variation to be not more than $\frac{1}{32}$ in., and, prior to shipment, shall have the burr occasioned by the saw cutting removed, and the ends made clean. No. 1 rails shall be free from injurious defects and flaws of all kinds.

No. 2 rails shall be accepted up to 5% of the whole order. They shall not have flaws in their heads of more than $\frac{1}{4}$ in., or in the flange of more than $\frac{1}{2}$ in. in depth, and, in the judgment of the inspector, these shall not be so numerous or of such a character as to render them unfit for recognized second-quality rail uses. The ends of No. 2 rails shall be painted white, and shall have two prick-punch marks on the side of the web near the heat number brand, and placed so as not to be covered by the splice-bars. Rails from heats which failed under the drop test shall not be accepted as No. 2 rails.

*Branding.*—The name of the maker, the weight of the rail, and the month and year of manufacture shall be rolled in raised letters on the side of the web; and the number of the blow shall be plainly stamped on each rail where it will not subsequently be covered by the splice-bars.

*Inspection.*—The inspector representing the purchaser shall have free entry to the works of the manufacturer at all times when the contract is being filled, and shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the finished

Report of the Committee on Rail Sections (continued).

material is furnished in accordance with the terms of these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment.

The manufacturer shall furnish the inspector, daily, with carbon determinations for each blow, and a complete chemical analysis every 24 hours, representing the average of the other elements contained in the steel, for each day and night turn. These analyses shall be made on drillings taken from small test ingots.

*For Basic Open-Hearth Rails.*—The specifications for rails made by the Basic Open-Hearth process shall be the same as for Bessemer rails, excepting that their chemical composition shall be:

| | 70 to 79 lb. Percentage. | 80 to 89 lb. Percentage. | 90 to 100 lb. Percentage. |
|---|---|---|---|
| Carbon | 0.53 to 0.63 | 0.58 to 0.68 | 0.65 to 0.75 |
| Phosphorus shall not exceed | 0.05 | 0.05 | 0.05 |
| Silicon " " " | .0.20 | 0.20 | 0.20 |
| Sulphur " " " | .0.06 | 0.06 | 0.06 |
| Manganese | 0.75 to 1.00 | 0.80 to 1.05 | 0.80 to 1.05 |

We respectfully submit the above report and request the discharge of your Committee.

JOSEPH T. RICHARDS, *Chairman;*
C. W. BUCHHOLZ,
E. C. CARTER,
S. M. FELTON,
RICHARD MONTFORT,
H. G. PROUT,
EDMUND K. TURNER,
ROBERT W. HUNT, *Secretary.*

The undersigned concurs in the foregoing report with the exception of the clause relating to the continuance of the present sections.

JOHN D. ISAACS.

Mr. George E. Thackray, upon consideration following the meeting at which the majority report was prepared, decided that he did not feel justified in signing that report, neither did he feel like making a minority report, and, therefore, thought it wise that the report be withheld for further consideration.*

ROBERT W. HUNT,
*Secretary, Special Rail Committee.*

*Subsequent to the presentation of the report of the Special Committee on Rail Sections at the Annual Meeting, Mr. George E. Thackray submitted a minority report, and, in order that the views of all members of that Committee be presented to the membership, it is printed herewith.

## Minority Reports.

PHILADELPHIA, December 27th, 1905.

*To the American Society of Civil Engineers,*

GENTLEMEN:

In the report and specification of your Special Committee on Rails some points are conflicting and should be further discussed before a final report is made. It is therefore suggested that the present report be considered a report of progress, and presented to the Society for discussion at the Annual Convention in June, 1906.

The report makes a strong plea for lower temperatures in rolling in order to secure better metal in the rails, and every effort should be made to accomplish this without making too radical changes in the methods of manufacture. The high carbons called for in the specification are contrary to this idea, and are more in line with the practice of relying on the chemical composition alone to give hardness in the rails. There is no trouble in getting hardness in this way, but the rails are likely to be brittle, and thus increase the number of breakages. The large number of rails, irrespective of section and weight, which are now breaking in service, cannot be ignored, and, if necessary, it would be better to stand some additional wear, if rails could be secured which would not break.

In all Tee-rails the thin flanges control the finishing temperature, and, in order to get a rail which could be rolled at a lower temperature, it has been suggested to add more metal to the bottom of the flange of the present Am. Soc. C. E. section in order to allow a lower finishing temperature in rolling and retain the advantages of the present wide head for bearing surface and side wear. This would not prevent the metal in the head from breaking off in the plane of the web, as at present. This breakage occurs in all weights of rails, and is generally due to piped steel or segregation.

In order to prevent the heads from breaking, it has been suggested to use one standard width of head for rails of 80 lb. and more, increasing the thickness of the head and of the flange as the weight increases, thus producing a stiffer rail in the heavier sections, with a head better suited to withstand the severe effect of worn wheels riding the edge of the head. Rails of 80 to 100 lb. of such sections, could be finished at the same temperature in rolling, and therefore be made of the same carbon steel.

Notwithstanding the advantages which might be derived from such rails, it would be ill-advised to recommend any change of section until every means has been exhausted for producing better steel, on account of the large commercial interests involving both the manufacturer and consumer.

WM. R. WEBSTER.

Report of the Committee on Rail Sections (continued).

DECEMBER 28TH, 1905.

*To the American Society of Civil Engineers,*

GENTLEMEN:

While concurring in the major portion of the conclusions arrived at by the majority of your Special Committee on Rails, the undersigned deems it his duty to present a minority report.

*Instruction No. 1.*—He agrees with the majority report.

*Instruction No. 2.*—He agrees with the majority report with the following addition: The attention of the Society is called to the fact that certain failures in service, especially of rails of maximum sections, can be traced to the uneven temperatures of the various parts of the sections when finished at the rolls due to the large cross-section of head and relatively small areas of flange and web. This very dangerous defect can alone be remedied by a very radical change of design which your Committee, with the data now at their command, do not feel authorized in recommending, but believe that the attention of the Society should be called to the matter as a subject for future investigation and report.

*Instruction No. 3.*—He agrees with the majority report.

*Instruction No. 4.*—He dissents from the conclusion of the majority report. He is of the opinion that specifications as prepared by the user should extend only to the quality of the finished material both chemically and physically, the details and methods of manufacture being left entirely to the producer, but that the requirements be made so rigid that only material made in accordance with the best state of the art will fill the specifications. He dissents from the opinion:

> "When rails of lighter sections were used, chemical conditions were not so important as with the heavier ones; this, because the rolling down of the steel to the smaller sections of necessity gave it more work, and also finished the rail at a lower temperature; thus producing a finer-grained and tougher metal. This partially explains why so many of the early steel rails gave good physical results, while their chemical composition was so irregular."

but believes that chemical composition was as important in the past as it is in the present, and equally so in all sections; the variations referred to can be accounted for by physical conditions rather than chemical composition.

As to other statements of the majority report under this clause he agrees.

*Instruction No. 5.*—He dissents from the clauses of the proposed specifications relating to methods of manufacture, and would omit the same. He agrees with those relating to quality and requirements of finished material, excepting as to carbon and manganese content.

He would also propose the addition of a test for tensile strength and elongation, the test piece to be cut from the head of the rail, and would add to the drop test a measure of limiting deflection.

He would also call attention to the following point; if a discard be required, it should be measured by a certain percentage of the ingot, and not by the length of the bloom.

The proposed method of regulating the finishing temperature will not necessarily accomplish the desired result, as the rail may be held prior to entering the finishing pass or at some other point until the proper finishing temperature be attained, while what is sought to be accomplished is that the ingot be worked throughout at a lower temperature than prevails in present practice.

He sees no reason why the carbon and manganese content, as specified for light sections, should be raised as the weight of the rails is increased, for the reason that the heavier the rail the more uneven the temperature at finishing throughout the various portions of the section, and the higher the carbon the more susceptible the steel to heat treatment, the heavier the rail the higher the temperature of the head at finishing; while, conversely, the higher the carbon the lower the working temperature should become. As long as we continue our present practice of using sections of such varying cross-sections as we have in our maximum weights, a high content of metalloids will always be a menace to successful service, which is not alone measured by wear of individual rails, but also by uniformity of results and freedom from sudden breakage.

His individual opinion is in favor of even a lower carbon content than proposed in the majority report, coupled with such physical requirements of finished material as will necessitate a rolling of the material at a lower temperature than now practiced.

Respectfully submitted,

PERCIVAL ROBERTS, JR.

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*To the American Society of Civil Engineers,*

GENTLEMEN:

Referring to the preliminary report of the majority of the Special Committee on Rails, the writer considers that there are some doubts regarding various points, the first of which relates to the reaffirmation of the American Society of Civil Engineers' sections.

It is not understood from the synopsis of the reports received from the railroad companies, how many of those who express themselves as satisfied with the sections, are using rails of 80 and 85 lb. per yd. and upward to 100 lb. per yd. in weight.

Recent experience with heavier sections of rails, 85 lb. per yd. and greater in weight, has shown that there have been some troubles

Report of the Committee on Rail Sections (continued).

caused by the shearing or splitting of the heads of these heavy sections under severe traffic, and as comparatively few roads use the heaviest sections, the opinion of the majority could not govern, as most of the railways, when considered individually, use rails of the lighter weights from 85 lb. per yd. and less. It would appear that in forming an opinion of the results obtained with the heavy sections the different sizes should be considered separately and a careful valuation made of the experience, with due regard to the mileage, character and amount of traffic. To state this briefly, it is believed that a majority of favorable opinions on the sections, counting each railroad as one vote, regardless of the size of the road and sections used, does not answer the question regarding the heavier sections.

The above question of heavy sections, however, is believed to be not so great a one as that of the impossibility of obtaining low-phosphorus Bessemer rails, for the reason that a very serious and practical difficulty presents itself in that part of the specifications requiring that phosphorus shall not exceed 0.085 per cent. As, although the Lake Superior Districts produced about 30 000 000 tons of ore last year, there was not nearly enough of low-phosphorus grade to supply the demand for rails of such composition, and only a very small part of the required output might be made to the proposed specifications. This is a vital point, as it is certainly wrong to ask for something that cannot be had.

As regards Open-Hearth rails, it seems that the slight experience had with them up to this time leaves this question in a very immature condition.

Under these circumstances, the undersigned does not feel warranted in signing the committee's report, and believes that the subject should receive their further attention.

GEO. E. THACKRAY.

Discussion on Report of Committee on Rail Sections.

THE PRESIDENT.—Gentlemen, you have heard the report of the Committee on Rail Sections. What action will you take?

FOSTER CROWELL, M. Am. Soc. C. E.—I move that the report of the Committee be received, and also that the minority reports of the Committee be received for further consideration.

THE PRESIDENT.—Gentlemen, one member of the Committee has asked that it be discharged, and one member requests that this report be referred to the Society for further discussion at the Annual Convention. Now, what is to be done?

JOSEPH O. OSGOOD, M. Am. Soc. C. E.—Is there any motion before the Society?

THE PRESIDENT.—Yes, Mr. Crowell has made a motion.

Mr. OSGOOD.—Has that motion been seconded?

THE PRESIDENT.—No.

Mr. OSGOOD.—Then I move that the report be received and the Committee continued.

The motion was seconded.

ROBERT W. HUNT.—As a member of that Committee, I suppose, from a strict parliamentary standpoint, if a committee does not finish its report, it should naturally be continued, but, at the same time, I do not think you can expect anything further, or any further work from this Committee. Eight out of the twelve members of this Committee have striven for four years to perform their duty, and to give you their best thought. Three of the members differed with us. It is not worth while to go into the details of the workings of that Committee, but, I think the members will agree with me, that we cannot hold out any hope that the Committee will be any closer together in June than it is now, and for that reason I think it is wise that the Society should not put itself on record as recommending the acceptance of the report of the Committee without careful thought. We will undoubtedly meet with great opposition on the part of the rail manufacturers of the country, and, while I believe it is very healthy to have that opposition, still the Society wants to be very careful in any position it takes.

I am confident that the status, so far as the Committee is concerned, will be the same next June as it is now, if it is continued in force.

Mr. OSGOOD.—I had in mind, when suggesting that the Committee should continue its work, that there was something more to be done, and if the Committee is discharged, it is a wrong process to appoint an entirely new Committee to take up the work; but, on the other hand, if this Committee is continued and any member feels that he cannot continue on the Committee, he can resign and another can be appointed in his place. I think the continuing of this old Committee and the appointment of new members to it, if necessary, will be better than the appointment of an entirely new Committee, to carry out the work if it is not already completed.

THE PRESIDENT.—Are there any further remarks? Mr. Osgood, will you please repeat your motion?

Mr. OSGOOD.—My motion is that the report of the Committee be received and the Committee continued.

THE PRESIDENT.—Are you ready for the question?

A MEMBER.—Question.

THE PRESIDENT.—Gentlemen, you have heard the motion. All in favor of Mr. Osgood's motion that the report be received and the Committee continued, say "aye."

("Ayes.")

THE PRESIDENT.—Those opposed, "no."

(No response.)

Report of the Committee on Concrete and Reinforced Concrete.

THE PRESIDENT.—The "ayes" have it, and the motion is carried. The report of the Special Committee on Concrete and Reinforced Concrete.

The Secretary of the Committee will please read the report.

The report was read by Mr. R. L. Humphrey, Secretary of the Committee, as follows:

## REPORT OF THE SPECIAL COMMITTEE ON CONCRETE AND REINFORCED CONCRETE.

*Mr. President and*
*Members of the American Society of Civil Engineers.*

GENTLEMEN:

Your Special Committee on Concrete and Reinforced Concrete desires to present the following report:

The duty of your Committee is to formulate rules for the use of concrete and reinforced concrete.

It has been found, however, that the necessary data for this purpose are not available in cognate form, and it is necessary to carry on such investigations as will secure the requisite data.

The investigations being conducted at the various technological institutions have received very careful consideration, and, as a result, the Committee has concluded that the information to be derived from this source, while valuable, is not sufficiently conclusive for use in the formulation of a report, most of this information being only on special phases of the subject.

At a meeting of the Committee held in New York on October 11th, 1905, it was decided to form a number of sub-committees for the collation of existing literature and the results of previous investigations. These sub-committees are now at work, and it is expected that the results of their labors will be presented to the Society at its next Annual Meeting.

It was suggested that the work being undertaken by the United States Geological Survey would yield the additional data desired, and, at a meeting held in Cleveland, June 21st, 1905, the Committee considered this proposition and finally instructed several of its members to prepare a plan of co-operation for its consideration. At the meeting held in Atlantic City, June 30th, 1905, a plan of co-operation was presented, which, after a thorough discussion, was adopted.

At a meeting of the Committee held in New York, December 12th, 1905, the Sub-Committee on Tests presented a programme for such investigations as it deemed desirable to make, with subdivisions, which, with a few minor amendments, was adopted; this programme will be elaborated further, as the work progresses.

These investigations, which it is estimated will take at least five years, will be carried on in the laboratories of the United States

Geological Survey, involving an estimated yearly expenditure by the United States Government of upwards of $20 000.

At the same meeting the Sub-Committee on Ways and Means was instructed to raise $10 000 for the present year, for the purpose of defraying the expenses of the Committee in compiling the results of these investigations and for formulating a report.

The Committee now has its work well under way and has taken steps to secure the requisite funds for its expenses.

As rapidly as possible, the Committee will report such data or information as it considers of value.

Your Committee asks that it be continued.

Respectfully submitted, for the Committee,

C. C. SCHNEIDER,
*Chairman;*
RICHARD L. HUMPHREY,
*Secretary.*

*Committee:*

C. C. SCHNEIDER,
RICHARD L. HUMPHREY,
J. E. GREINER,
W. K. HATT,
OLAF HOFF,
ROBERT W. LESLEY,
J. W. SCHAUB,
EMIL SWENSSON,
A. N. TALBOT,
J. R. WORCESTER.

THE PRESIDENT.—Gentlemen, you have heard the report. What will you do with it?

MORRIS R. SHERRERD, M. Am. Soc. C. E.—I move that the report be received and that the Committee be continued.

The motion, being duly seconded, was carried unanimously.

**Amendments to the Constitution.**

THE PRESIDENT.—The amendments to the Constitution. The Assistant Secretary will please read the proposed amendments to the Constitution.

The Assistant Secretary read the following:

The following suggested amendments to the Constitution are submitted:

"Amend Article II, Section 2. as follows: insert after the word 'Civil' in the first line 'Engineer who shall have reached a position of recognized standing in the profession, in its several branches including.' Also strike out all of the second line beginning with the word 'Electrical' and insert 'and Electrical Engineering or in Architecture or Marine Architecture.' Also strike out all after the word 'age' in the fourth line.

Amendments to the Constitution (continued).

"The section will then read:

"2. A Member shall be a Civil Engineer who shall have reached a position of recognized standing in the profession, in its several branches, including Military, Naval, Mining, Mechanical and Electrical Engineering or in Architecture or Marine Architecture. He shall be at the time of admission to membership not less than thirty years of age."

The foregoing amendments are proposed by the following Corporate Members: Jas. Owen, Ralph H. Chambers, Philip W. Henry, Walter H. Sears, S. Whinery, A. P. Boller, Foster Crowell.

THE PRESIDENT.—Some letters on the subject have been received, and these will be read by the Assistant Secretary.

The Assistant Secretary then read letters from Messrs. Charles H. Ledlie, L. S. Randolph, Dugald C. Jackson, Benjamin Thompson, Edward M. Boggs, Ellis B. Noyes, Joseph Lillich, A. B. Wood, Robert L. Lund and Mark L. Ireland.

Discussion on Amendments to the Constitution.

S. WHINERY, M. Am. Soc. C. E.—In order to get this matter formally and in proper shape before the Society, I want to say that there seems to be quite a strong conviction among the membership that a part of the Constitution ought to be changed, in some way, but there does not seem to be much unanimity as to what these changes should be.

It is very difficult, in a meeting like this, to give such a subject proper attention. I think that in dealing with a question of this kind the best results can be obtained by appointing a carefully chosen Committee, who can take up the subject and give it all the attention necessary, and report to the Society.

I do not wish to cut off further discussion of the subject at this time, but wish to say that I shall, at the proper time, move for adoption, that the amendment be referred to a committee of five members to be appointed by the President, which committee shall report to the next Annual Convention, what, if any, changes it deems advisable, in the present classification of the membership of the Society, or any modification in each grade of membership, and submit any amendment to these amendments which they may recommend.

I will not move the adoption of that resolution now, because it may have the effect of cutting off any discussion that we might have on it here to-day, which would be valuable to the committee. I think the discussion on the subject should proceed now, and at the proper time I will move the adoption of that motion.

Mr. CROWELL.—I think this subject is of extreme importance to the Society and its work. This is not the first time, by any means, that the subject has been brought forward, but I think the letters which have been read are indicative of the fact that the subject has become of very vital importance. When Mr. Whinery gets ready to

offer his motion I will be very glad to second it. I do not see why the adoption of that motion should come after the discussion. In fact, I do not think it is worth while to spend much time now in discussing the question, for the reason that Mr. Whinery has just stated—that justice cannot be done to such a subject in a meeting of this kind. It requires more thought, and requires comparison with the various standards of other societies and other organizations, and with our own past history. I think it would be well for Mr. Whinery to offer his motion now, and then any discussion that seems proper can be had upon it.

THE PRESIDENT.—Will you offer that motion now, Mr. Whinery?

Mr. WHINERY.—If it will not have the effect of ending the discussion, I will offer it.

THE PRESIDENT.—Discussion on that motion will then be in order.

Mr. CROWELL.—I second the motion.

THE PRESIDENT.—In order to have the motion understood, will you please repeat it?

The Assistant Secretary read the motion, as follows:

"Moved, that the amendments be referred to a committee of five Corporate Members, to be appointed by the President, which committee shall report to the next Annual Convention what, if any, changes they deem advisable in the present classification of the membership of the Society, or in the qualifications for each grade of membership; and submit any amendments to these amendments which they may recommend."

THE PRESIDENT.—Discussion on this motion is now in order. Are there any remarks?

A MEMBER.—Question.

EDWARD P. NORTH, M. Am. Soc. C. E.—Mr. President, I would like to offer an amendment to that motion, and have it seconded: That the five Corporate Members mentioned in the motion be increased by one Associate and one Junior. I think that, in the consideration of such a question, these two elements are quite important classes in our Society, and should be represented.

The amendment was accepted.

THE PRESIDENT.—You have heard the motion, gentlemen. Those in favor of it say "aye."

The motion as amended was carried unanimously.

Nominating Committee.

THE PRESIDENT.—The appointment of members of the Nominating Committee for each of the seven geographical districts, to serve for two years, is now in order. The Assistant Secretary will please read the nominations.

THE ASSISTANT SECRETARY.—I will first read the nominations for District No. 1.

Nominating Committee (continued).

*District No. 1.*—Total number of votes received, 90; distributed as follows:

| | |
|---|---|
| JOHN H. COOK | 37 |
| ALFRED NOBLE* | 2 |
| CLEMENS HERSCHEL | 2 |
| GEORGE B. FRANCIS | 2 |
| A. P. BOLLER | 2 |
| EDLOW W. HARRISON | 2 |
| C. L. HARRISON* | 2 |
| O. F. NICHOLS | 2 |
| J. V. DAVIES | 2 |

The following have received one vote each:

| | |
|---|---|
| HENRY R. ASSERSON, | JOSEPH MAYER, |
| JOSIAH A. BRIGGS, | WILLIAM C. MERRYMAN, |
| C. W. BUCHHOLZ, | RUDOLPH P. MILLER, |
| R. S. BUCK, | MACE MOULTON, |
| GEORGE HALLETT CLARK, | CHARLES H. MYERS, |
| D. C. N. COLLINS, | FREDERICK S. ODELL, |
| ALFRED CRAVEN,* | C. J. PARKER, |
| J. J. R. CROES,* | C. D. POLLOCK, |
| J. H. EDWARDS, | WILLIAM A. PRATT, |
| ROBERT GILES, | ROBERT RIDGWAY, |
| CHARLES H. GRAHAM, | FRANK W. SKINNER, |
| GEORGE A. HARWOOD, | FRANK J. SPRAGUE, |
| WILLIAM J. HASKINS, | S. C. THOMPSON, |
| PHILIP W. HENRY, | R. H. TINGLEY, |
| R. HERING, | HENRY VIER, |
| WILLIAM R. HILL, | JOHN C. WAIT, |
| HENRY W. HODGE, | CLEMENT I. WALKER, |
| OTIS E. HOVEY, | CHARLES D. WARD, |

SAMUEL WHINERY.

On motion, duly seconded, John H. Cook, Assoc. M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the First District.

THE ASSISTANT SECRETARY.—The nominations for District No. 2 are as follows:

*District No. 2.*—Total number of votes received, 51; distributed as follows:

| | |
|---|---|
| LEONARD METCALF | 26 |
| J. R. WORCESTER | 6 |
| HIRAM A. MILLER | 3 |
| EDWIN D. GRAVES | 2 |

* Ineligible.

The following have received one vote each:

| | |
|---|---|
| C. F. Allen, | A. B. Hill, |
| Dexter Brackett, | F. W. Hodgdon, |
| Robert A. Cairns, | William E. McClintock, |
| Otis F. Clapp, | Henry Manley, |
| F. S. Curtis, | William Harley Moore, |
| Alexis H. French, | Charles W. Sherman, |
| Richard A. Hale, | E. K. Turner. |

On motion, duly seconded, Leonard Metcalf, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Second District.

The Assistant Secretary.—The nominations for District No. 3 are as follows:

*District No. 3.*—Total number of votes received, 69; distributed as follows:

| | |
|---|---|
| A. H. Sutermeister | 37 |
| James H. Edwards | 12 |
| Phelps Johnson | 4 |
| William A. Haven | 3 |

The following have received one vote each:

| | |
|---|---|
| W. A. Brackenridge, | Olin H. Landreth, |
| E. R. Cary, | P. A. Peterson, |
| A. P. Davis, | George A. Ricker, |
| W. T. Jennings, | E. Gybbon Spilsbury, |
| Wallace C. Johnson, | Charles F. Stowell, |
| John Kennedy, | A. H. Van Cleve, |

J. Van der Hoek.

On motion, duly seconded, A. H. Sutermeister, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Third District.

The Assistant Secretary.—The nominations for District No. 4 are as follows:

*District No. 4.*—Total number of votes received, 100; distributed as follows:

| | |
|---|---|
| Edgar Marburg | 41 |
| Percival M. Sax | 19 |
| William Copeland Furber | 9 |
| D. D. Carothers | 3 |
| Thomas H. Johnson | 3 |
| Thomas W. Symons | 2 |

Nominating Committee (continued).

The following have received one vote each:

| | |
|---|---|
| JAMES MURRAY AFRICA, | FREDERIC C. KUNZ, |
| KENNETH ALLEN, | J. K. LYONS, |
| J. C. BLAND, | ALEXANDER MACKENZIE, |
| JOHN N. CHESTER, | D. E. MCCOMB, |
| MENDES COHEN, | E. K. MORSE, |
| ARTHUR P. DAVIS, | F. H. NEWELL, |
| PAUL DIDIER, | ROBERT VAN A. NORRIS, |
| B. T. FENDALL, | H. H. QUIMBY, |
| C. E. GRUNSKY, | L. Y. SCHERMERHORN, |
| L. M. HAUPT, | WILLIAM L. SIBERT, |
| MORRIS KNOWLES, | EMIL SWENSSON,* |

FRANK WILCOX.

On motion, duly seconded, Edgar Marburg, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Fourth District.

THE ASSISTANT SECRETARY.—The nominations for District No. 5 are as follows:

*District No. 5.*—Total number of votes received, 105; distributed as follows:

| | |
|---|---|
| JOHN W. ALVORD | 29 |
| GARDNER S. WILLIAMS | 26 |
| WILLARD BEAHAN | 15 |
| H. G. KELLEY | 9 |
| JOSEPH RIPLEY | 2 |

The following have received one vote each:

| | |
|---|---|
| ONWARD BATES,* | RALPH MODJESKI,* |
| W. L. BRECKENRIDGE, | AUGUSTUS MORDECAI, |
| CHARLES C. BROWN, | FRANK C. OSBORN, |
| THEODORE L. CONDRON, | ISHAM RANDOLPH, |
| WILLIAM DE LA BARRE, | JAMES RITCHIE, |
| MALVERD A. HOWE, | L. W. RUNDLETT, |
| CLARENCE W. HUBBELL, | J. W. SCHAUB, |
| H. G. KELLEY, | HARRY E. TALBOTT, |
| JESSE LOWE, | W. D. TAYLOR, |
| DANIEL MCCOOL, | GAYLORD THOMPSON, |
| BENJAMIN MCKEEN, | C. A. WILSON, |
| DABNEY H. MAURY, | GEORGE Y. WISNER. |

On motion, duly seconded, John W. Alvord, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Fifth District.

* Ineligible.

THE ASSISTANT SECRETARY.—The nominations for District No. 6 are as follows:

*District No. 6.*—Total number of votes received, 64; distributed as follows:

| | |
|---|---|
| IRA G. HEDRICK | 12 |
| A. H. ZELLER | 12 |
| W. W. COE | 3 |
| J. F. COLEMAN | 2 |
| GEORGE G. EARL | 2 |
| WILLIAM H. COURTENAY | 2 |
| JULIAN W. KENDRICK | 2 |
| J. F. HINCKLEY | 2 |
| HUNTER MCDONALD* | 2 |
| A. M. SCOTT | 2 |

The following have received one vote each:

| | |
|---|---|
| DANIEL BONTECOU, | MARSHALL MORRIS, |
| STEPHEN P. BROWN, | E. T. D. MYERS, |
| C. S. BURNS, | J. A. OCKERSON, |
| W. E. GUNN, | HENRY B. RICHARDSON, |
| E. A. HARPER, | S. BENT RUSSELL, |
| B. M. HARROD, | F. W. SCARBOROUGH, |
| J. N. HAZLEHURST, | J. E. SIRRINE, |
| W. B. W. HOWE, | H. R. STANFORD, |
| CHARLES HUMPHREYS, | HENRY M. STEELE, |
| J. L. LUDLOW, | C. A. WENTWORTH, |
| ROBERT MOORE,* | C. H. WEST, |

NISBET WINGFIELD.

On motion, duly seconded, A. H. Zeller, Assoc. M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Sixth District.

THE ASSISTANT SECRETARY.—The nominations for District No. 7 are as follows:

*District No. 7.*—Total number of votes received, 57; distributed as follows:

| | |
|---|---|
| FRANK O. MARVIN | 16 |
| FRANKLIN RIFFLE | 4 |
| ARTHUR L. ADAMS | 3 |
| R. B. MARSHALL | 2 |
| ROBERT B. BURNS | 2 |

* Ineligible.

Nominating Committee (continued).

The following have received one vote each:

| | |
|---|---|
| JEREMIAH AHERN, | J. B. LIPPINCOTT, |
| D. D. CLARKE, | M. L. LYNCH, |
| WILLIAM E. DAUCHY, | F. B. MALTBY, |
| W. W. FOLLETT, | S. D. MASON, |
| EDWARD GILLETTE, | WILLIAM G. RAYMOND, |
| R. H. GRESHAM, | G. H. ROBINSON, |
| C. E. GRUNSKY, | D. W. ROSS, |
| W. W. HARTS, | W. H. SANDERS, |
| JOHN B. HAWLEY, | JAMES D. SCHUYLER, |
| F. W. D. HOLBROOK, | H. A. SUMNER, |
| C. T. JOHNSTON, | T. U. TAYLOR, |
| W. H. JONES, | A. J. WILEY, |
| A. E. KASTL, | CHARLES F. WILLIAMS, |
| A. V. KELLOGG, | C. B. WING, |
| LEWIS KINGMAN, | E. T. WRIGHT. |

On motion, duly seconded, Frank O. Marvin, M. Am. Soc. C. E., was appointed a member of the Nominating Committee for the Seventh District.

THE PRESIDENT.—Has the Secretary any announcements to make?

Award of Prizes.

THE ASSISTANT SECRETARY.—I have to report that the Board of Direction has awarded the prizes for the year ending July, 1905, in accordance with the report of the Committee appointed to recommend the awards, as follows:

PHILADELPHIA, PENNA., DEC. 26TH, 1905.

*To the Board of Direction,*
AMERICAN SOCIETY CIVIL ENGINEERS.

GENTLEMEN:—Your Committee appointed for the purpose, recommend the award of prizes for papers, published during the year ending July 1, 1905, as follows:

The Norman Medal to Mr. C. C. Schneider, for Paper No. 997, "The Structural Design of Buildings."

The Thomas Fitch Rowland Prize to Messrs. Charles L. Harrison and Silas H. Woodard, for Paper No. 981, "Lake Cheesman Dam and Reservoir."

The Collingwood Prize for Juniors to Mr. E. P. Goodrich, for Paper No. 983, "Lateral Earth Pressures and Related Phenomena."

JAMES CHRISTIE,
J. T. FANNING,
F. C. KUNZ,
*Committee.*

Announcements.

The Thirty-eighth Annual Convention of the Society will be held at the Hotel Frontenac, Thousand Islands, New York, June 26th to 29th, 1906.

I have to announce the death of Francis Edward Snyder, elected Member September 6th, 1905; died December 23d, 1905.

The Assistant Secretary also made some announcements relative to the programme of the Annual Meeting.

THE PRESIDENT.—We will now take an intermission until such time as the tellers' report is ready to be submitted.

(Recess.)

THE PRESIDENT.—(After recess.) Gentlemen, the report of the tellers is ready.

THE ASSISTANT SECRETARY.—The tellers report: Report of Tellers.

**Report of Tellers Appointed to Canvass the Ballot for the Election of Officers at the Annual Meeting, January 17th, 1906.**

| | |
|---|---|
| Total number of ballots received | 845 |
| Defective | 24 |
| Total number counted | 821 |

*For President:*

| | |
|---|---|
| Frederic P. Stearns | 817 |
| Josiah A. Briggs | 1 |
| E. L. Corthell | 1 |
| Fayette S. Curtis | 1 |

*For Vice-Presidents:*

| | |
|---|---|
| Onward Bates | 811 |
| Bernard R. Green | 801 |
| H. G. Kelley | 1 |
| A. C. Cunningham | 1 |
| Almon B. Atwater | 1 |
| John A. Ockerson | 1 |
| E. C. Shankland | 1 |
| George S. Webster | 1 |

*For Treasurer:*

| | |
|---|---|
| Joseph M. Knap | 815 |
| John Thomson | 1 |

*For Directors:*

| | |
|---|---|
| George Gibbs | 802 |
| J. Waldo Smith | 808 |
| Emil Swensson | 796 |
| James M. Johnson | 802 |
| Wynkoop Kiersted | 799 |
| William B. Storey, Jr. | 800 |
| E. Marburg | 1 |

Report of Tellers (continued).

| | |
|---|---|
| E. M. Scofield | 1 |
| John Sterling Deans | 2 |
| Arthur P. Davis | 1 |
| A. L. Johnson | 1 |
| L. W. Rundlett | 1 |
| L. L. Tribus | 1 |
| J. F. Coleman | 2 |
| James Murray Africa | 1 |
| Arthur L. Adams | 2 |
| William G. Wilkins | 2 |
| James H. Brace | 1 |
| W. W. Coe | 1 |
| B. M. Wagner | 1 |
| Frank O. Marvin | 1 |
| E. B. Cushing | 1 |
| A. V. Kellogg | 1 |
| William G. Brenneke | 1 |
| George E. Gifford | 1 |
| A. B. Corthell | 1 |
| William H. Wiley | 1 |
| Ashbel E. Olmsted | 1 |
| E. Wegmann | 1 |
| Arthur Hider | 1 |
| J. A. Omberg, Jr | 1 |
| H. H. McClintock | 1 |
| George S. Greene, Jr | 1 |
| J. A. Atwood | 1 |
| Robert A. Cummings | 1 |
| J. A. L. Waddell | 1 |
| Thomas W. Symons | 1 |
| E. J. Beard | 1 |
| George B. Francis | 1 |

W. D. KELLEY,
GEO. L. WILSON,
J. A. KNIGHTON,
*Tellers.*

Officers Elected.

THE PRESIDENT.—The following having received a majority of the votes cast are herewith declared to be elected as officers of this Society for the ensuing year:

*As President,* Frederic P. Stearns. (Applause.)

*As Vice-Presidents,* Onward Bates and Bernard R. Green;

*As Treasurer,* Joseph M. Knap;

*As Directors,* George Gibbs, J. Waldo Smith, Emil Swensson, James M. Johnson, Wynkoop Kiersted and William B. Storey, Jr.

The Chair will appoint Mr. Green and Mr. Swensson as a committee to conduct Mr. Stearns to the platform. (Applause.)

President Stearns Introduced.

THE PRESIDENT.—I take pleasure in introducing to you Mr. Stearns, President-elect of the American Society of Civil Engineers. (Applause.)

Remarks by President Stearns.

PRESIDENT STEARNS.—Gentlemen of the American Society of Civil Engineers, I thank you for your cordial greeting.

Permit me to express to you my grateful appreciation of the high honor that you have conferred upon me in electing me as President of this Society which we all esteem.

The mere mention of the name—The American Society of Civil Engineers—brings with it suggestions of a Society which stands for the maintenance of the highest professional standing among its members; of a Society whose members accomplish marvels in these days of progress; of a Society rapidly growing both in numbers and resources, and capable of accomplishing great results, such as were produced by the International Engineering Congress; it brings with it also the memories of those who are not with us, eminent and honored members who were devoted to its interests.

In accepting the Presidency and the responsibility which goes with it, I recognize my own limitations; but, with your co-operation, I will try to achieve the best measure of success that lies within my power.

I thank you once more, gentlemen, for the honor conferred. (Applause.)

Adjourned.

The meeting then adjourned.

## EXCURSIONS AND ENTERTAINMENTS AT THE FIFTY-THIRD ANNUAL MEETING.

**Wednesday, January 17th, 1906.**—After the business meeting, lunch for about 500 members was served at 1.30 P. M. at the Society House.

At 3 P. M., excursions under special guidance were organized, and visited the following engineering works: The Fifty-ninth Street Power House of the Interborough Rapid Transit Company, George H. Pegram, M. Am. Soc. C. E., Chief Engineer; the Blackwell's Island Bridge, O. F. Nichols, M. Am. Soc. C. E., Chief Engineer; the Pennsylvania Railroad Terminal Station, George C. Clarke, M. Am. Soc. C. E., Resident Engineer; the Waterside Stations of the New York Edison Company, Thirty-eighth to Fortieth Streets and East River, Thomas F. Murray, General Manager.

At 9 P. M. there was a Reception, with dancing, in the Society House, at which the attendance was about 350.

**Thursday, January 18th, 1906.**—The day was devoted to an excursion, by steamer, to the New York Navy Yard, by invitation of Rear-Admiral Joseph B. Coghlan, Commandant.

The party met at the pier at the foot of West Forty-first Street (North River) at 10 A. M., and embarked on the steamer *Valley Girl*, kindly furnished through the courtesy of General Howard Carroll and the Hon. John H. Starin. The vessel proceeded down the North River, around the Battery, and directly to the Navy Yard, where the party was received by the Commandant and officers in charge. All the buildings, dry docks and other features of the Yard were open for inspection, and quite a large number visited the United States Battleship *Connecticut*, which was being fitted out.

On leaving the Navy Yard the steamer proceeded up the East River as far as Riker's Island, thus affording a view of the various bridges, and incidentally other engineering works on the river front. Lunch was served on the boat, and the party landed at the Recreation Pier at the foot of East Twenty-fourth Street at about 5 P. M.

In the evening, at the Society House, Charles S. Gowen, M. Am. Soc. C. E., presented a paper entitled, "The Changes at the New Croton Dam," which was illustrated with lantern slides, and the subject was discussed by W. R. Hill, M. Am. Soc. C. E. This was followed by a social and informal "smoker," at which there was an attendance of more than 500 members and guests.

The following list contains the names of 605 members, of various grades, who registered as being in attendance at the Annual Meeting. The list is incomplete, on account of the failure of many members to register, and it does not contain the names of any of the guests of the Society or of individual members:

Abbot, F. W....New York City
Abbott, H.....New York City
Aiken, W. A.....Pittsburg, Pa.
Alderman, C. A.,
Worcester, Mass.
Allen, C. H.....New York City
Allen, C. L.....Utica, N. Y.
Allen, E. Y., South Orange, N. J.
Allen, H. C.....Syracuse, N. Y.
Allen, W. A.....New York City
Andrews, Horace..Albany, N. Y.
Ash, Dorsey...Wilmington, Del.
Aspinwall, T.....Boston, Mass.
Atkinson, A....New York City
Auryansen, F..Brooklyn, N. Y.
Averill, F. L..Washington, D. C.

Babcock, W. S..New York City
Backes, W. J..Weehawken, N. J.
Bacon, John W.Danbury, Conn.
Bailey, G. I....New York City
Baird, H. C.....New York City
Baker, H. C., Jr.New York City
Baldwin, F. H..Brooklyn, N. Y.
Baldwin, W. J..New York City
Ball, E. S.....New York City
Bamford, W. B..New York City
Bardol, F. V. E..Buffalo, N. Y.
Barney, Percy C.Brooklyn, N. Y.
Bartoccini, A....New York City
Bartram, G. C....Boston, Mass.
Basinger, J. G...New York City
Beerbower, G. M.New York City
Belden, E. T..New Haven, Conn.
Belknap, J. M..Ashtabula, Ohio
Belknap, W. E..New York City
Bell, T. K....Philadelphia, Pa.
Belzner, T.....New York City
Benton, L. S....New York City
Berg, Walter G..New York City
Berger, Bernt...New York City
Bernegau, C. M..New York City
Berry, G.....Brooklyn, N. Y.
Betts, R. T.....New York City
Beugler, E. J...New York City
Bishop, G. H.Middletown, Conn.
Bishop, H. K....Hudson, N. Y.
Bissell, H.....Boston, Mass.
Blakeley, G. H..Paterson, N. J.
Boardman, H. E.New York City
Boecklin, Werner.New York City
Bogart, John....New York City
Boller, A. P.....New York City
Bond, G. W., Jr.,
Weehawken, N. J.
Boucher, W. J..New York City
Bouton, H....Jersey City, N. J.
Bowman, A. L...New York City
Boyd, J. C.....New York City
Brace, J. H.....New York City
Brackenridge, J. C.,
Brooklyn, N. Y.
Braine, L. F....New York City
Bramwell, G. W.New York City
Braslow, Barnett.New York City
Breuchaud, J....Yonkers, N. Y.
Breuchaud, J. R..Yonkers, N. Y.
Briggs, R. E....Mexico, Mexico
Brinckerhoff, H. W.,
New York City
Brown, L. L....New York City
Brown, S. C....New York City
Brown, T. E....New York City
Brown, W. P....New York City
Bruce, J. M....New York City
Bryson, Andrew.New Castle, Del.
Buchholz, C. W..New York City
Buck, L. L.....New York City
Buck, R. S.....New York City
Bullock, W. D..Providence, R. I.
Burgess, G. H..New York City
Burr, W. H.....New York City
Burrowes, H. G..New York City
Bush, H. D.....Baltimore, Md.
Bush, L.....East Orange, N. J.
Buzzell, J. W.....Boston, Mass.

Cantine, E. I.East Orange, N. J.
Carlile, T. J....New York City
Carpenter, A. W.New York City

Carter, A. E....New York City
Chambers, H. J..New York City
Chapleau, S. J.....Ottawa, Ont.
Chester, J. N.....Pittsburg, Pa.
Christian, G. H.New York City
Christy, G. L....New York City
Clapp, S. K.....New York City
Clark, G. Hallett.New York City
Clark, J. A., Jr.,
East Orange, N. J.
Clarke, G. C....New York City
Clarke, St. John...Bogota, N. J.
Coe, W. W.....Roanoke, Va.
Coffin, Amory...New York City
Coffin, T. Amory.New York City
Cole, H. O.....New York City
Collier, B. C....New York City
Collingwood, F..Elizabeth, N. J.
Conger, A. A....Albany, N. Y.
Cook, J. H.....Paterson, N. J.
Coombs, S. E....New York City
Cooper, S. L....Yonkers, N. Y.
Cornell, G. B....New York City
Cornell, J. N. H.New York City
Corthell, A. B...New York City
Cotton, J. P.....Newport, R. I.
Coverdale, W. H.New York City
Crane, C. A.....New York City
Crane, J. S.....Newark, N. J.
Craven, Alfred..New York City
Crehore, W. W..New York City
Cresson, B. F., Jr.,
New York City
Creuzbaur, R. W.New York City
Crowell, Foster..New York City
Cuddeback, A. W.Paterson, N. J.
Cummings, Noah.New York City
Curtis, F. S.....Boston, Mass.
Curtis, V. P...Worcester, Mass.

Daily, J. A..East Orange, N. J.
Dakin, A. H., Jr.New York City
Dalrymple, F. W.Bayonne, N. J.
Davies, J. V....New York City
Davis, A. L.....New York City
Davis, C.....Edgeworth, Pa.
Davis, J. L.....New York City
Davis, R. B.....Boston, Mass.
Davis, W. R.....Albany, N. Y.
Dean, Luther....Taunton, Mass.
Deans, J. S....Phœnixville, Pa.
Decker, J. H.Atlantic City, N. J.
Devin, G.....New York City
Diamant, A. H..New York City
Dilks, L. C.....New York City
Dimon, D. Y....New York City
Dorrance, W. T..New York City
Doty, A. Duane..New York City
Dougherty, R. E.New York City
Downes, A. K...New York City
Drew, C. D.....Brooklyn, N. Y.
Dunham, H. F..New York City
Dunlap, F. C..Philadelphia, Pa.

Easby, M. W..Philadelphia, Pa.
Edwards, D. G..New York City
Edwards, H. W..New York City
Edwards, J. H....Oxford, N. Y.
Ellis, J. W....Woonsocket, R. I.
Elwell, C. C.New London, Conn.
Evans, L. H....New York City

Farrington, H...Yonkers, N. Y.
Fenton, L. G....New York City
Fetherston, J. T.,
New Brighton, N. Y.
Fickes, E. S.....Pittsburg, Pa.
Fisher, E. A...Rochester, N. Y.
Fisher, F. D....New York City
Fisher, H. T....New York City
Fisher, W.....Philadelphia, Pa.
Fletcher, R.....Hanover, N. H.
Flinn, Alfred D..New York City
Forchhammer, H.New York City
Ford, P. D.....New York City
Ford, W. H...Philadelphia, Pa.
Forgie, James...New York City
Fort, E. J.....New York City
Foster, E. H....New York City
Francis, G. B....New York City

Francis, H. N..Providence, R. I.
Fraser, C. E.....New York City
French, A. W..Worcester, Mass.
French, J. B....Jamaica, N. Y.
Frick, Walter....Lewisburg, Pa.
Frost, G. S.....Brooklyn, N. Y.
Fuller, F. L.....Boston, Mass.
Fuller, W. B.....Pittsburg, Pa.
Fuller, W. E....New York City
Furber, W. C..Philadelphia, Pa.

Gahagan, W. H.Brooklyn, N. Y.
Gartensteig, C...New York City
Gaston, L. P....New York City
Gifford, G. E....New York City
Giles, A. L....Providence, R. I.
Giles, Robert...Lawrence, N. Y.
Gillen, W. J..Croton Falls, N. Y.
Gillespie, R. H..New York City
Gillette, H. P...New York City
Goad, C. E....Toronto, Canada
Goldsborough, J. B.,
Croton-on-Hudson, N. Y.
Goodrich, E. P..New York City
Goodridge, J. W.New York City
Gould, J. W. duB.New York City
Gould, W. T....New York City
Gow, C. R.....Boston, Mass.
Gowen, C. S....Ossining, N. Y.
Gowen, S.....Phœnixville, Pa.
Grady, C. B..West Orange, N. J.
Graham, C. H..New York City
Graham, J. M...New York City
Grant, T. H....Red Bank, N. J.
Gray, J. C.....Brooklyn, N. Y
Gray, J. H.....New York City
Gray, W.....New York City
Green, B. R..Washington, D. C.
Green, C. N.....New York City
Green, F. M.....New York City
Greene, Carleton.New York City
Greene, G. S., Jr.New York City
Greenlaw, R. W..New York City
Gregory, C. E...New York City
Greiner, J. E....Baltimore, Md.
Griffin, A. J....Brooklyn, N. Y.
Grimes, E. L.....Troy, N. Y.
Grimm, C. R....New York City
Guthrie, K. O..Brooklyn, N. Y.

Hager, A. B..Rutherford, N. J.
Haight, S. S....New York City
Haines, C. W...Richmond, Va.
Hale, H. M.....New York City
Hall, L. W.....Syracuse, N. Y.
Hall, M. W.....New York City
Hallsted, J. C...New York City
Hanavan, W. L..New York City
Harrison, C. L..New York City
Harrison, E. W.,
Jersey City, N. J.
Harte, C. R..New Haven, Conn.
Harwood, G. A..New York City
Haskins, W. J..New York City
Hauck, W.....Brewster, N. Y.
Hayes, H. W.....Boston, Mass.
Hazard, S..White Plains, N. Y.
Hazelton, C. W.,
Turners Falls, N. Y.
Hazen, Allen....New York City
Hazen, John V..Hanover, N. H.
Hazen, W. N....New York City
Hazlett, R...Wheeling, W. Va.
Heald, E. C..Washington, D. C.
Herbert, H. M.,
Bound Brook, N. J.
Hering, Rudolph.New York City
Hermanns, F. E..New York City
Herschel, C.....New York City
Hewes, Virgil H.New York City
Hewitt, C. E....Trenton, N. J.
Hildenbrand, W..New York City
Hill, A. B...New Haven, Conn.
Hill, G.....New York City
Hill, W. R.....Brooklyn, N. Y.
Hillyer, W. R.,
West Brighton, N. Y.
Hoag, S. W., Jr..New York City
Hodgdon, F. W...Boston, Mass.
Hodge, Henry W.New York City

Hoffman, N. B. K., New York City
Hogan, J. P....New York City
Holbrook, Percy.New York City
Hollyday, R. C..New York City
Honness, G. G...Katonah, N. Y.
Hood, R. H.....New York City
Horton, S.....Garrison, N. Y.
Hough, D. L....New York City
Hovey, O. E....New York City
How, R. W.....New York City
Howard, E. E..Kansas City, Mo.
Howard, J. L.....Boston, Mass.
Howe, H. J.....New York City
Howell, R. P..Philadelphia, Pa.
Howes, D. W....New York City
Hoyt, W. E....Rochester, N. Y.
Hubbell, G. S....New York City
Hudson, C. W..Phœnixville, Pa.
Hughes, H. J..Cambridge, Mass.
Humphrey, R. L., Philadelphia, Pa.
Hunt, C. A....Brooklyn, N. Y.
Hunt, Robert W...Chicago, Ill.
Huntington, G. D., Watertown, N. Y.

Ingersoll, C. M., New Haven, Conn.

Jacobs, R. H....New York City
Jacoby, H. S.....Ithaca, N. Y.
Janvrin, N. H...New York City
Japp, H.Long Island City, N. Y.
Johnson, A. L....St. Louis, Mo.
Johnson, L. J..Cambridge, Mass.
Jonson, E. F....New York City
Jordan, W. F., White Plains, N. Y.
Just, G. A.....New York City

Kastl, A. E.....Clinton, Mass.
Keays, R. H.....New York City
Keith, H. C.....New York City
Keller, C. L.....Chicago, Ill.
Kelley, W. D....Yonkers, N. Y.
Kenly, W. W....New York City
Kenney, E. F..Philadelphia, Pa.
King, C. C., West New Brighton, N. Y.
King, P. S.....New York City
King, W., Jr...New York City
Kinsley, T. P....New York City
Kirchner, P. A..New York City
Knap, Edgar D..New York City
Knap, Joseph M.New York City
Knickerbocker, J...Troy, N. Y.
Knight, Frank B.New York City
Knighton, J. A..New York City
Knowlton, T....New York City
Kolb, H. J.....Brooklyn, N. Y.
Kuichling, E....New York City

LaChicotte, H. A.New York City
Lamb, Richard..New York City
Landreth, O. H., Schenectady, N. Y.
Langthorn, J. S.New York City
Lavis, F.....New York City
Leather, B. H...New York City
Leavitt, C. W., Jr., New York City
Lee, D. R....Middletown, N. Y.
Lee, W. B.....Hillburn, N. Y.
Leffingwell, F. D.Montclair, N. J.
Leisen, T. A..Wilmington, Del.
Lentilhon, E....New York City
Leonard, H. R.Philadelphia, Pa.
Lesley, R. W..Philadelphia, Pa.
Lewis, L. H.....New York City
Lewis, N. P.....New York City
Lieb, J. W., Jr..New York City
Lindenthal, G....New York City
Logan, W. S....Arlington, N. J.
Long, E. McL...New York City
Look, M. J.....Katonah, N. Y.
Loomis, H...Mt. Vernon, N. Y.
Lowinson, O....New York City
Lucas, G. L.....New York City
Lundie, John....New York City

MacCracken, G. G., New York City
MacGregor, R. A., New York City
Machen, H. B...New York City
MacNab, G. T...New York City
McComb, C. O..Syracuse, N. Y.
McComb, D. E., Washington, D. C.
McCormack, C. W., New York City
McDaniel, A. B..New York City
McHarg, Leslie..New York City
McKenzie, T. H.Hartford, Conn.
McMinn, T. J..New York City
McPherson, R. H., New York City
Magor, Basil....New York City
Malukoff, A. J..New York City
Manley, Henry....Boston, Mass.
Marple, W. M....Scranton, Pa.
Mead, C. A.....New York City
Meem, J. C.....New York City
Merrill, O.....New York City
Merriman, M., South Bethlehem, Pa.
Merriman, T.....Shokan, N. Y.
Merritt, D. S..Tarrytown, N. Y.
Merryman, W. C., New York City
Metcalf, Leonard..Boston, Mass.
Meyer, H. C....New York City
Meyers, C. W...New York City
Miller, Frank...New York City
Miller, H. A.....Boston, Mass.
Miller, H. C.....New York City
Miller, R. P....New York City
Mills, C. M....Philadelphia, Pa.
Moisseiff, L. S..New York City
Moore, W. H.New Haven, Conn.
Moran, D. E....New York City
Morrison, H. J..Syracuse, N. Y.
Morse, C. M.....Buffalo, N. Y.
Moulton, Mace..New York City
Myers, J. H....New York City
Neumeyer, R. E..Bethlehem, Pa.
Newbrough, W..Evanston, Wyo.
Nichols, C. H...New York City
Noble, A.....New York City
Noble, F. C....Brooklyn, N. Y.
North, E. P.....New York City
Norton, A. G...Otisville, N. Y.
Nunn, P. N.....Provo, Utah
Nye, A. S.....New York City

Oastler, W. C...New York City
Odell, F. S..Port Chester, N. Y.
Olmsted, A. E...New York City
Opdyke, S. B., Jr., New York City
Orr, Alex....Gloversville, N. Y.
Osborn, F. C...Cleveland, Ohio
Osgood, J. O..Jersey City, N. J.
Otagawa, M.....Tokyo, Japan
Owen, A. E....Montclair, N. J.
Owen, James....Newark, N. J.
Oxholm, T. S., West New Brighton, N. Y.

Park, J. C.....Cranford, N. J.
Parker, A. McC..New York City
Parker, C. J.....New York City
Parker, W.....Boston, Mass.
Parmley, W. C..New York City
Parsons, G. W.....Steelton, Pa.
Parsons, H. deB....Troy, N. Y.
Pegram, G. H...New York City
Pemoff, J. J.....New York City
Perkins, P. S..Providence, R. I.
Perrilliat, A...New Orleans, La.
Perry, J. P. H...New York City
Peterson, J.....Brooklyn, N. Y.
Plympton, G. W.Brooklyn, N. Y.
Polk, W. A.....New York City
Pollock, C. D....Brooklyn, N. Y.
Pope, J. H.....New York City
Potter, A.....New York City
Potter, H. W....New York City
Potts, Clyde.....New York City
Powers, C. V. V.New York City

Preston, H. W....Elmira, N. Y.
Prince, A. D....New York City
Proctor, R. F....New York City
Prout, H. G.....New York City
Pruyn, F. L.....New York City

Quimby, E. R...New York City
Quinby, C. E....Ludlow, Mass.
Quincy, C. F.....Chicago, Ill.

Ray, David H...New York City
Read, R. L.....Malden, Mass.
Reynolds, J. O..New York City
Rice, G. S.....New York City
Richards, J. T.Philadelphia, Pa.
Richardson, C...New York City
Richardson, T. F..Clinton, Mass.
Richmond, J....Yonkers, N. Y.
Ridgway, R.....New York City
Riedel, J. C.....New York City
Rights, L. D..New Haven, Conn.
Robbins, A. A...New York City
Roberts, G. T.....Buffalo, N. Y.
Robertson, M. P.,
New Orleans, La.
Rogers, H. L....Jamaica, N. Y.
Rogge, J. C. L..New York City
Root, W. S.....New York City
Rose, C. C.....Scranton, Pa.
Rowell, G. F....New York City
Russell, R. L....Brooklyn, N. Y.
Ryan, M. H.....New York City

Sabin, A. H.....Flushing, N. Y.
Sabine, E. D....New York City
Safford, E. S....New York City
Sanborn, F. B.Cambridge, Mass.
Sax, P. M....Philadelphia, Pa.
Sayles, R. W...New York City
Schaeffer, Amos..New York City
Schall, F. E.,
South Bethlehem, Pa.
Schneider, A..Rutherford, N. J.
Schneider, C. C.,
Philadelphia, Pa.
Scott, A. M.,
Charleston-Kanawha, W. Va.
Sears, W. H....New York City
Sergeant, G., Jr..New York City
Shailer, R. A.....Boston, Mass.
Shannahan, J. N.,
Gloversville, N. Y.
Shepherd, F. C..New York City
Sherman, R. W....Utica, N. Y.
Sherrerd, M. R....Newark, N. J.
Shertzer, T. B...New York City
Shoemaker, M. N..Newark, N. J.
Sickman, A. F..Holyoke, Mass.
Simpson, G.....New York City
Simpson, G. F..New York City
Sinclair, F. O...Burlington, Vt.
Sitt, W. T.....New York City
Skinner, F. W...New York City
Sleeper, G. E.....Newark, N. J.
Slocum, C. L..New Haven, Conn.
Smith, A.....New York City
Smith, C. E.....Ossining, N. Y.
Smith, E. M....New York City
Smith, H. C...Philadelphia, Pa.
Smith, H. S..Wilkes-Barre, Pa.
Smith, J. Waldo.New York City
Smith, M. H....Yonkers, N. Y.
Smith, Oberlin.Bridgeton, N. J.
Smith, W. F....New York City
Snow, C. H.....New York City
Snow, J. P.....Boston, Mass.
Snyder, F. A....New York City
Snyder, G. D....New York City
Soper, G. A.....New York City
Sorzano, J. F...Brooklyn, N. Y.
Spear, P. H....Elizabeth, N. J.
Spear, W. E...Providence, R. I.
Spencer, T. N..Philadelphia, Pa.
Spencer, W. T.,
New Haven, Conn.
Splitstone, C. H..Allegheny, Pa.
Spofford, C. M..New York City
Spooner, A. N...New York City
Sprague, E. L., Jr.,
New York City

Stanton, R. B...New York City
Stearns, F. L....New York City
Stearns, F. P.....Boston, Mass.
Stepath, C.....New York City
Stern, E. W.....New York City
Stevenson, W. F.New York City
Stockton, John..New York City
Stoddard, G. C..New York City
Strachan, J....Brooklyn, N. Y.
Strobel, C. L.....Chicago, Ill.
Strouse, W. F...Baltimore, Md.
Stuart, A. A....Brooklyn, N. Y.
Stuart, F. L....New York City
Suhr, O. B.....Provo, Utah
Swensson, E.....Pittsburg, Pa.
Swift, W. E....Yonkers, N. Y.
Swindells, J. S.Mt. Kisco, N. Y.

Taber, G. A.....New York City
Taft, J. R.....New York City
Tait, H..Long Island City, N. Y.
Tait, J. G.....New York City
Temple, J. C..Philadelphia, Pa.
Temple, W. H. G.,
Providence, R. I.
Thackray, G. E..Johnstown, Pa.
Theban, J. G....New York City
Thomas, G. E...New York City
Thomas, S. R..Hokendauqua, Pa.
Thomes, E. H..New York City
Thompson, S. C.,
New York City
Thompson, S. E.,
Newton Highlands, Mass.
Thomson, A., Jr..New York City
Thomson, G. H..New York City
Thomson, John..New York City
Thomson, S. F..Brooklyn, N. Y.
Thomson, T. K..New York City
Tidd, A. W.....Pawling, N. Y.
Tighe, J. L.....Holyoke, Mass.
Tillson, G. W..Brooklyn, N. Y.
Tingley, R. H..New York City
Tomkins, Calvin.New York City
Tompson, G. M...Boston, Mass.
Torrey, J. E....New York City
Tozzer, A. C....Brooklyn, N. Y.
Trautwine, J. C., Jr.,
Philadelphia, Pa.
Travell, W. B...New York City
Tretter, G. A...Phœnixville, Pa.
Tribus, L. L....New York City
Triest, W. G....New York City
Trotter, A. W...New York City
Trout, C. E.....New York City
Tucker, R. F....New York City
Tucker, W. C...New York City
Tull, R. W.....New York City
Turner, D. L....New York City
Turner, E. K.....Boston, Mass.
Tuttle, A. S....New York City

Ulrich, Daniel..Katonah, N. Y.
Usina, D. A....New York City

Vail, J. J.....Rahway, N. J.
Van Brakle, J. O.,
New York City
Van Buren, J. D.,
New Brighton, N. Y.
Van Buskirk, C. R.,
New York City
Van Suetendael, A. O.,
Yonkers, N. Y.
Verveer, E. L...New York City
Vier, Henry....New York City
Vinton, T. MacI..New York City
Vorce, C. B.....New York City
Vredenburgh, W., Jr.,
New York City

Wachter, C. L..New York City
Wadsworth, J. E.,
New York City
Wagner, J. C..Philadelphia, Pa.
Wagner, S. T..Philadelphia, Pa.
Waldron, S. P..New York City
Walker, C. I....New York City
Walker, J. W....Pittsburg, Pa.

Wallace, H. U...New York City
Ward, C. R.....New York City
Wason, L. C.....Boston, Mass.
Waterhouse, J..New York City
Watkins, F. W.,
White Plains, N. Y.
Watson, Merritt.New York City
Webster, W. R..Philadelphia, Pa.
Welton, B. F...New York City
Wendt, E. F.....Pittsburg, Pa.
West, C. H....Greenville, Miss.
West, O. J.....Chicago, Ill.
Weston, R. S.....Boston, Mass.
Weymouth, F. E.,
Glendive, Mont.
Wheeler, H. R..New York City
Wheeler, R. N..New York City
Whinery, Samuel.New York City
White, L.....New York City
White, W. M....New York City
Wiggin, E. W.New Haven, Conn.
Wilcock, F.....Brooklyn, N. Y.
Wilcox, F.....Pittsburg, Pa.
Wild, H. J.....Meriden, Conn.
Wilgus, W. J....New York City
Wilkes, J. K.,
New Rochelle, N. Y.
Wilkins, G. S...New York City
Williams, B. L., Jr.,
West Orange, N. J.
Williamson, F. S.,
New York City
Wills, A. J...Newburgh, N. Y.
Wilson, C. W. S..New York City
Wilson, G. L.,
Minneapolis, Minn.
Winsor, F. E.....Boston, Mass.
Wölfel, P. L...Philadelphia, Pa.
Woodard, S. H..New York City
Woodbury, C. J. H.,
Boston, Mass.
Woodcock, H. W.,
Brooklyn, N. Y.
Woolley, A. F.,
Washington, D. C.
Wright, A. W....Pomona, Cal.
Wright, J. B....New York City

Yates, E. A.....New York City
Yates, W. H.....New York City
Young, E. E..Auburndale, Mass.

Zollinger, L. R.,
Philadelphia, Pa.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, March 7th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Theory of Continuous Columns," by Ernst F. Jonson, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for January, 1906.

**Wednesday March 21st, 1906.**—8.30 P. M.—At this meeting a paper, entitled "New Facts about Eye-Bars," by Theodore Cooper, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for January, 1906.

**Wednesday, April 4th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Panama Canal," by A. G. Menocal, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

**Wednesday, April 18th, 1906.**—8.30 P. M.—At this meeting a paper, entitled "A Complete Analysis of General Flexure in a Straight Bar of Uniform Cross-Section," by L. J. Johnson, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

**Wednesday, May 2d, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Control of Hydraulic Mining in California by the Federal Government," by William W. Harts, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

### ANNUAL CONVENTION.

The Thirty-eighth Annual Convention of the Society will be held at The Hotel Frontenac, Thousand Islands, New York, on June 26th to 29th, 1906.

## PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 410 Penn Avenue, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner, Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten- Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesbrough, England.

**Civil Engineers' Society of St. Paul,** St. Paul, Minn.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

# ACCESSIONS TO THE LIBRARY.

From January 8th to February 13th, 1906.

## DONATIONS.*

### PRACTICAL CEMENT TESTING.

By W. Purves Taylor, Jun. Am. Soc. C. E. Cloth, 9 x 6, illus,. 9 + 320 pp. New York, The Myron C. Clark Publishing Co., 1906. $3 net.

It is stated in the preface that the author aims to give a complete description of the methods of handling practical tests of cement. This volume has been designed primarily for the use of the student, the novice, and the practical operator in conducting actual routine tests of cement to determine its suitability for purposes of construction; but it is hoped that both the expert and the engineer who directs this work may also find something of interest in its pages. The general scope includes a description of the properties of cement, the object of the various tests, the methods of conducting them, the common influences and errors most likely to affect the determinations, and the practical interpretation of the results finally obtained. No attempt has been made to consider the practical use of cement and concrete, except in so far as the conditions of actual work regulate the use of the various tests, while the data given are also applicable more to the conduct of tests than to the final use of the material. In other words, the book is intended to cover only the methods and the application of the tests of cement commonly used in routine work, and not to consider theoretical properties, investigations of a research character, nor the use of cement. There is a bibliography and an index of three-and-a-half pages.

Gifts have also been received from the following:

Am. Mathematical Soc. 1 pam.
Arango, R. M. 1 pam.
Atlantic City, N. J.-Board of Water Commrs. 1 pam.
Boston-Transit Comm. 1 bound vol.
Brit. Fire Prevention Committee. 1 pam.
Brooklyn, N. Y.-Commr. of Public Works. 1 bound vol.
Brooks, Frederick. 205 pam.
Brown Hoisting Machinery Co. 1 bound vol.
Brown, Le Grand. 1 pam.
Cambridge Mass.-Water Board. 1 pam.
Carnegie Inst. of Washington. 1 vol.
Coll. degli Ing. e Arch. in Palermo. 1 vol.
Colo.-State Agri. Exper. Station. 1 pam.
Colo. Springs, Colo.-Health Dept. 1 pam.
Conn.-Shell Fish Commrs. 1 pam.
Deutsch-Am. Tech. Verbandes. 1 pam.
Dist. of Columbia-Street Cleaning Dept. 1 pam.
Eng. Soc. of Japan. 1 pam.
Fish, J. C. L. 1 pam.
Godfrey, Edward. 1 bound vol.
Great Britain-Under Secy. of State for India. 28 bound vol., 16 vol., 11 pam.
Hague, C. A. 2 pam.
Harrod, B. M. 6 pam. 1 vol.
Indiana-State Board of Health. 1 bound vol.
Inst. of Civ. Engrs. 1 bound vol.
Inst. of Civ. Engrs. Glasgow Assoc. of Students. 1 pam.
Kansas City Southern Ry. Co. 1 pam.
Lake Mohonk Conference. 1 vol.
Lewis, N. P. 1 bound vol.
London, Ont.-Board of Water Commrs. 1 pam.
Mass.-Land and Harbor Commrs. 1 bound vol.
Mass. Inst. of Tech. 1 pam.
Met. Ry. Co. 1 pam.
Mich.-Secy. of State. 1 bound vol.
Mobile, Jackson & Kansas City R. R. Co. 1 pam.
National Arts Club. 1 pam.
National Board of Fire Underwriters, Committee of Twenty. 2 vol.
New England Cotton Mfrs. Assoc. 1 bound vol.
New South Wales-Govt. Statistician. 3 pam.
New York City-Board of Health. 1 pam.
New York City-Dept. of Docks and Ferries. 1 bound vol.
*New York City Record.* 3 bound vol.
New York Univ. 1 vol.
Norway-Inspector of Mines. 1 pam.
Ontario, Canada-Provincial Board of Health. 1 pam.
Pennsylvania R. R. System. 1 bound vol.
Platt, T. C. 2 vol.
Ry. Signal Assoc. 1 vol.
Richmond, Fredericksburg & Potomac R. R. Co. 1 pam.
Rochester, N. Y.-Dept. of Public Works. 1 vol.
Royal Philosophical Soc. of Glasgow. 1 vol.
Sachs, Ing.-und Arch. Vereins. 2 vol.
Smithsonian Inst. 1 vol.
South Eastern Ry. Co. 2 pam.

* Unless otherwise specified, books in this list have been donated by the publishers.

Texas-R. R. Comm. 1 vol.
Thompson, R. A. 27 pam.
Transvaal-Irrig. Comm. 1 vol.
Twelvetrees, W. N. 1 pam.
U. S. Bureau of Forestry. 1 pam.
U. S. Bureau of Labor. 1 vol.
U. S. Bureau of Statistics. 1 pam.
U. S. Bureau of Steam Eng. 1 pam.
U. S. Bureau of the Census. 1 bound vol.
U. S. Coast and Geodetic Survey. 1 bound vol., 1 pam., 1 chart.
U. S. Engr. School. 1 pam.
U. S. Geol. Surv. 35 vol., 1 bound vol.
U. S. Interstate Commerce Comm. 18 pam.
U. S. Lake Survey Office. 6 charts.
U. S. Naval Observatory. 1 vol.
U. S. Ordnance Dept. 1 bound vol.
U. S. War Dept. 14 specif.
U. S. Weather Bureau. 1 bound vol.
Univ. of Ill. Agri. Exper. Station. 1 pam.
Univ. of Ill. Eng. Exper. Station. 1 pam.
Univ. of Mich. 1 pam.
Univ. of Mich. Eng. Soc. 1 vol.
Vulcanite Portland Cement Co. 1 pam.
Washington, D. C.-Library of Congress. 1 bound vol.
Western Australia-Dept. of Mines. 1 vol.
Western Australia-Geol. Surv. 4 pam.
Whipple, C. C. 1 pam.
Willson, F. N. 1 bound vol.
Woolson, I. H. 1 pam.
Worcester Polytechnic Inst. 1 vol.

## BY PURCHASE.

**The Mechanical Engineering of Collieries, Vol. II.** By T. Campbell Futers. London, The Chichester Press, 1905.

**Sea-Coast Erosion and Remedial Works.** By R. G. Allanson-Winn. London, St. Bride's Press, Ltd.

**Steam Boilers,** Their History and Development. By H. H. P. Powles. London, Archibald Constable & Co., Ltd., 1905.

**Architect, Owner and Builder Before the Law.** By T. M. Clark. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1905.

**Theory of Structures and Strength of Materials.** By Henry T. Bovey. Fourth Edition. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1905.

**Outlines of Practical Hygiene.** By C. Gilman Currier, M.D., Assoc. Am. Soc. C. E. New York, E. B. Treat & Co., 1905.

**Economic Geology of the United States.** By Heinrich Ries. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1905.

**Building Construction and Superintendence,** Parts 1–2. By F. E. Kidder. New York, William T. Comstock, 1905.

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## SUMMARY OF ACCESSIONS.

January 8th to February 13th, 1906.

| | |
|---|---|
| Donations (including 33 duplicates) | 458 |
| By purchase | 9 |
| Total | 467 |

## MEMBERSHIP.

### ADDITIONS.

#### MEMBERS.

| | | Date of Membership. |
|---|---|---|
| ALLIN, THOMAS DAVID. 101 E. Walnut St., Pasadena, Cal. | | Jan. 3, 1906 |
| BRENNEKE, WILLIAM GEORGE. (Brenneke & Fay, Cons. Civ. Engrs.), 1009 Fullerton Bldg., St. Louis, Mo. | Assoc. M.<br>M. | Mar. 5, 1902<br>Jan. 2, 1906 |
| CRIDER, JAMES LELAND. Div. Engr., N. Y., Westchester & Boston Ry., 220 S. Fulton Ave., Mt. Vernon, N. Y. | | Jan. 3, 1906 |
| CUSHMAN, WILLIAM HERBERT. Chf. Engr., Juniata Hydro-Elec. Co., Huntingdon, Pa. | | Jan. 3, 1906 |
| DUFFIES, EDWARD JOHN. Asst. U. S. Engr., Harbor Beach, Mich. | | Jan. 3, 1906 |
| FAY, EDWARD BAYRD. (Brenneke & Fay, Cons. Engrs.), 1009 Fullerton Bldg., St. Louis, Mo. | Assoc. M.<br>M. | Jan. 8, 1902<br>Jan. 2, 1906 |
| FREELAND, CHESTER SHEPARD. Care, Wm. Hood, 1340 Merchants Exchange Bldg., San Francisco, Cal. | | Jan. 3, 1906 |
| LUPFER, EDWARD PAYSON. Asst. Chf. Engr., Buffalo & Susquehanna Ry., 990 Ellicott Sq., Buffalo, N. Y. | | Jan. 3, 1906 |
| NICHOLSON, FRANK LEE. 205 N. Park Ave., Norfolk, Va. | | Dec. 6, 1905 |
| POLLEYS, WILLIAM VAUGHAN. Res. Engr., Westinghouse, Church, Kerr & Co., Thompson House, East Liverpool, Ohio. | | Jan. 3, 1960 |

#### ASSOCIATE MEMBERS.

| | | |
|---|---|---|
| ADAMS, EDWARD MAGUIRE. 1st Lieut., Adjutant, 3d Battalion of Engrs., Fort Leavenworth, Kans. | Jun.<br>Assoc. M. | Oct. 7, 1902<br>Jan. 3, 1906 |
| BELL, THOMAS K. Chf. Engr., Wm. Wharton, Jr. & Co., Inc., 25th and Washington Ave., Philadelphia, Pa. | | Jan. 3, 1906 |
| BLACKWELL, PAUL ALEXANDER. Canonsburg, Pa. | Jun.<br>Assoc. M. | Dec. 4, 1900<br>Jan. 3, 1906 |
| COCHRANE, VICTOR HUGO. 55 Water St., Pittsburg, Pa. | | Oct. 4, 1905 |
| DEGRAFF, HARRY WESTBROOK. Asst. Engr. in Chg., Res. No. 3, N. Y. State Barge Canal, Fonda, N. Y. | | Jan. 3, 1906 |
| DEMPSTER, OSBORNE JOEL. Herkimer, N. Y. | | Jan. 3, 1906 |
| DILKS, LORENZO CARLISLE. Contr. Mgr., The Eastern Steel Co., 71 Broadway, New York City | | Jan. 3, 1906 |
| HARSHBARGER, ELMER DWIGHT. First Asst. Engr., Bureau of Filtration, Dept. of Public Works, Pittsburg, Pa. | Jun.<br>Assoc. M. | Nov. 5, 1901<br>Jan. 3, 1906 |
| HERMANNS, FRANK EDWARD. With J. G. White & Co., 43 Exchange Pl., New York City | | Jan. 3, 1906 |

ASSOCIATE MEMBERS (*Continued*).

| | Date of Membership. |
|---|---|
| PETERSON, JOHN. Chf. Draftsman, Dept. of Water Supply, Gas and Electricity, Borough of Brooklyn, Room 41, Municipal Bldg., Brooklyn, N. Y. | Jan. 3, 1906 |
| SARGENT, ARTHUR WINTHROP. U. S. Engr. Office, Seattle, Wash. | Sept. 6, 1905 |
| SHAW, ARTHUR MONROE. Cons. and Contr. Engr., Dixon, Ill. | Jan. 3, 1906 |
| SHERMAN, EDWARD CLAYTON. Asst. Engr., Charles River Basin Comm., 367 Boylston St., Boston, Mass. | Jan. 3, 1906 |
| STODDARD, RAYMOND FRENCH. Asst. Engr., N. Y., N. H. & H. R. R. Co., Milford, Conn. | Jan. 3, 1906 |
| THOMSON, SAMUEL FORSYTHE. Asst. Engr., Rapid Transit R. R. Comm., 4 Court Sq., Brooklyn, N. Y. | Jan. 3, 1906 |
| WAIT, OWEN ADELBERT. Designing Engr., Great Northern Power Co., 316 Providence Bldg., Duluth, Minn. | Dec. 6, 1905 |

ASSOCIATES.

| | |
|---|---|
| BRUCE, JOHN MOFFATT. 42 Broadway, New York City. | Jan. 3, 1906 |
| CONARD, WILLIAM ROBERTS. Burlington, N. J. | Jan. 3, 1906 |

JUNIORS.

| | |
|---|---|
| ABRAMS, DUFF ANDREW. 703 South 3d St., Champaign, Ill. | Jan. 2, 1906 |
| BLACK, EDWARD FRYLING. 323 Baronne St., New Orleans, La. | Oct. 31, 1905 |
| COLLINS, FRANCIS WINFIELD. 535 West 142d St., New York City. | Jan. 2, 1906 |
| ESTEN, HOWARD FOSS. 102 Cedar St., Pawtucket, R. I. | Jan. 2, 1906 |
| FEDERLEIN, WALTER GOTTLIEB. Asst. Engr. in Chg. of Sewers, Hudson Companies, 111 Broadway, New York City. | Jan. 2, 1906 |
| HIGGINS, CHARLES HOUCHIN. Engr. for F. M. Stillman Co., 26 Exchange Pl., Jersey City, N. J. | Jan. 2, 1906 |
| HITT, RODNEY. Associate Editor, *Railroad Gazette*, 83 Fulton St., New York City. | Sept. 5, 1905 |
| HOVEY, RAY PALMER. With the Am. Bridge Co., P. O. Box 459, Ambridge, Pa. | Jan. 2, 1906 |
| HUNTSMAN, FRANK C. Macon, Mo. | Sept. 5, 1905 |
| LEE, CHARLES HAMILTON. 1108 Union Trust Bldg., Los Angeles, Cal. | Jan. 2, 1906 |
| LOUGHRAN, HAROLD SCOTT. Asst. Engr., Dept. of Sewers, City Hall, New Rochelle, N. Y. | Jan. 2, 1906 |
| MAUPIN, EDGAR STAPLES. U. S. Govt. Fleet, Greenville, Miss. | Sept. 5, 1905 |

JUNIORS (*Continued*).

| | Date of Membership. |
|---|---|
| NICHOL, HENRY SCHELL. With Milliken Bros., 11 Broadway, New York City | Jan. 2, 1906 |
| PENDLETON, DAVID ELLIOTT. Box 404, Vicksburg, Miss. | Jan. 2, 1906 |
| POWELL, WILLIAM JENNER. U. S. Navy Barge No. 122, Care, Postmaster, Mobile, Ala. | Jan. 2, 1906 |
| SHEMA, JOSEPH. 2239 Essex St., Baltimore, Md. | Oct. 3, 1905 |
| WYMAN, ALFRED MARSHALL. Asst. Engr., Rapid Transit Comm., 203 North 16th St., E. Orange, N. J. | Jan. 2, 1906 |

## RESIGNATIONS.

### MEMBERS.

| | Date of Resignation. |
|---|---|
| GREENE, BENJAMIN DWIGHT | December 31, 1905 |

## DEATHS.

BOTH, CARL CHRISTIAN ADOLPH. Elected Member, September 2d, 1891; died January 12th, 1906.

BOWMAN, JOSEPH HOCKMAN. Elected Associate Member, December 2d, 1903; date of death unknown.

GIBSON, WILLIAM, JR. Elected Associate, September 5th, 1888; died April 19th, 1905.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(January 7th to February 9th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefouille Economique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Review de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elect. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.

(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Street Railway Review*, Chicago, 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.

## LIST OF ARTICLES.

### Bridge.

The Ferry Bridge across the Ship Canal at Duluth, Minnesota.* C. A. P. Turner, M. Am. Soc. C. E. (54) Vol. 55.

A Few Points in the Design of Reinforced Concrete Arches. B. R. Leffler, Assoc. M. Am. Soc. C. E. (54) Vol. 55.

A Rational Form of Stiffened Suspension Bridge.* Gustav Lindenthal, M. Am. Soc. C. E. (54) Vol. 55.

Theory and Formulas for the Analytical Computation of a Three-Span Suspension Bridge with Braced Cable.* Leon S. Moisseiff, Assoc. M. Am. Soc. C. E. (54) Vol. 55.

A New Swing Bridge at Copenhagen, Denmark.* H. C. V. Moeller. (54) Vol. 55.

The Reconstruction of the Baltimore and Ohio Railroad Bridge over the Ohio River, at Benwood, West Virginia.* J. E. Greiner, M. Am. Soc. C. E. (54) Vol. 55.

The Strengthening and Maintenance of Early Iron Bridges.* William Marriott, M. Inst. C. E. (63) Vol. 162.

Some further Tests of Reinforced Concrete Beams; C., M. & St. P. Ry. J. J. Harding. (4) Dec.

Some Notable American Railway Bridges.* James G. Walton. (10) Jan.

The Lower Chords of the Island Span of the Blackwell's Island Bridge.* (14) Jan. 6.

The Design of High Abutments. Wm. M. Torrance. (13) Jan. 11.

Main Vertical and Inclined Posts, Island Span, Blackwell's Island Bridge.* (14) Jan. 27.

Substructure of Potomac River Highway Bridge, Washington, D. C.* (14) Jan. 27.

Ueber die Berechnung von Schiffbrücken mit Gelenken.* H. Müller-Breslau. (49) Pts. 1-3, 1906.

Amerikanische Klappbrücken.* Georg v. Hanffstengel. (82) Serial beginning Jan. 6.

### Electrical.

Unsolved Problems in Electrical Engineering. Rookes Evelyn Bell Crompton, M. Inst. C. E. (63) Vol. 162.

A Study of a Single-Phase Series Motor.* George I. Rhodes. (7) Dec.

A Note on the Calculation of the Armature Reaction of Alternators.* Waldo V. Lyon. (7) Dec.

The Measurement of High Frequency Currents and Electric Waves. J. A. Fleming. (29) Serial beginning Dec. 29.

Electric Mains for Power Transmission Work. John T. Morris. (Abstract of Paper read before the Junior Inst. of Engrs.) (73) Dec. 29.

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**Electrical—(Continued).**

Power Plant Economics. Henry G. Stott. (42) Jan.
A Self-Exciting Alternator.* E. F. Alexanderson. (42) Jan.
Notes on Heavy Electric Switch Gear. J. Whitcher. (Abstract of Paper read before the Rugby Eng. Soc.) (73) Jan. 5.
The "Kaiserwerke" Electricity Works in the Tyrol.* (73) Jan. 5.
Wave Shapes in Three-Phase Transformers.* R. C. Clinker. (73) Jan. 5.
The Electrical Equipment at Messrs. J. Hopkinson & Co.'s Works, Huddersfield.* (26) Jan. 5.
Electric Lighting at Buncrana, Co. Donegal.* (26) Jan. 5.
Power Generation and Distribution on the System of the Public Service Corporation of New Jersey.* (17) Serial beginning Jan. 6.
Turbo Alternator for Glasgow.* (17) Jan. 6.
The Marion (Hackensack River) Station of the Public Service Corporation of New Jersey.* (27) Jan. 6.
The Architecture of Continental Power Plants.* (27) Jan. 6.
Exposed Circuit Wiring.* Louis J. Auerbacher. (27) Jan. 6.
District Supply in Rural Communities.* (27) Jan. 6.
Central Station Economics in Massachusetts: A Study of Two Typical Medium-Sized Companies. (27) Jan. 6.
Core Type Transformers for High Tension Power Transmission.* A. H. Pikler. (27) Jan. 6.
North Mountain Power Company's Hydro-Electric Plant.* (27) Jan. 6; (14) Jan. 6.
The London-Glasgow Underground Telegraph System.* (26) Serial beginning Jan. 12.
The London-Glasgow Telegraph Cable.* (73) Jan. 12.
Notes on a Wireless Telegraph Station.* C. C. F. Monckton. (73) Jan. 12.
Design of Turbo-Alternators.* H. S. Meyer. (73) Jan. 12.
Specifications for Line Wire. F. F. Fowle. (Paper read before the Ry. Signal Assoc.) (40) Jan. 12.
Hydro-Electric Installation at Sewalls Falls, N. H.* (18) Jan. 13.
The Electrical Distribution System of the Public Service Corporation of New Jersey.* G. U. G. Holman. (27) Serial beginning Jan. 13.
The Marion Power Station of the Public Service Corporation of New Jersey.* (14) Jan. 13.
The Post Office Telephone System: The "City" Exchange.* (26) Serial beginning Jan. 26.
Electric Power Distribution in North Wales.* (73) Serial beginning Jan. 26.
The New Post Office City Telephone Exchange.* (73) Jan. 26.
A Modern Central-Station Plant.* (64) Feb.
Lightning Protection.* J. V. E. Titus. (Paper read before the Ohio Interurban Ry. Assoc.) (17) Feb. 3.
The Springfield, Ill., Light, Heat and Power Co.'s Station and System.* (27) Feb. 3.
The DeForest Syntonic System of Wireless Telegraphy. A. Frederick Collins. (19) Feb. 10.
Zur Theorie der Wechselstromkreise. Leo Lichtenstein. (82) Serial beginning Jan. 20.
Ueber Hochspannungsisolatoren. J. Pusch. (80) Jan. 30.

**Marine.**

Shipbuilding for the Navy. Lord Brassey, Assoc. Inst. C. E. (63) Vol. 162.
The Cruiser.* William Hovgaard. (Read before the Soc. of Naval Archts. and Marine Engrs.) (7) Dec.
Submarine Signaling.* Henry R. Gilson. (7) Dec.
The Largest Turbine Steamship in the World: The *Carmania* of the Cunard Line.* Archibald S. Hurd. (10) Jan.
A Shipbuilding Cableway.* (12) Jan. 19.
Torsion Indicator Diagrams of Marine Engines.* (11) Jan. 26.
Le Paquebot à Turbines *Carmania* de la Compagnie Cunard.* L. Piaud. (33) Jan. 16.
Der Transatlantische Turbinendampfer *Carmania.** W. Kaemmerer. (48) Jan. 6.
Dockanlage für Torpedoboote auf der Kaiserlichen Werft Kiel.* Ph. von Klitzing. (48) Jan. 20.

**Mechanical.**

Preliminary Report of the Committee Appointed on the 6th of November, 1903, to Consider and Report to the Council on the Standards of Efficiency of Internal Combustion Engines.* (63) Vol. 162.
A Portable Apparatus for the Analysis of Flue Gases. Charles Joseph Wilson. (63) Vol. 162.
The Strength of Shafts Subject to Small Forces Rhythmically Applied. Charles Chree, Henry Riall Sankey, M. Inst. C. E., and William Ernest Wyatt Millington, Stud. Inst. C. E. (63) Vol. 162.

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**Mechanical—(Continued).**

Advantages and Applications of the Electric Drive. F. B. Crocker and M. Arendt. (6) Nov.
The Oxygen Blow-Pipe in Iron and Steel Welding.* (22) Dec. 29.
Tests of De Laval Steam Turbine.* Thomas B. Morley. (11) Dec. 29.
Standard Alloys. John F. Buchanan. (From *The Foundry.*) (47) Dec. 30.
Testing of High-Power Modern Gas Engines.* William H. Spiller. (41) Jan.
The Conditions of Fan-Blower Design. Walter B. Snow. (10) Jan.
Power in Tall Office Buildings: Its Cost and Distribution.* Charles H. Benjamin. (10) Jan.
Heat Insulation: Its Principles as Related to Cold Storage Practice. J. B. d'Homergue. (58) Jan.
A New Machine for Bending Tests.* E. Probst. (67) Jan.; (62) Feb. 1.
The Action of Slightly Alkaline Waters on Iron. Cecil H. Cribb. (Abstract of Paper read before the Soc. of Public Analysts.) (11) Jan. 5.
Note on Steam Turbines.* H. Riall Sankey, M. Inst. C. E. (11) Jan. 5.
The Oechelhauser Gas-Engine.* (11) Serial beginning Jan. 5.
Modern Gas Engine Power Plants.* Franz Koester. (14) Jan. 6.
The New Works of the Milwaukee Gas Light Co.* (13) Jan. 11.
The "Ados" $CO_2$ Recorder.* (11) Jan. 12.
The Guillery Hardness-Testing Apparatus.* (11) Jan. 12.
Methods of "Changing Speed" in Electric Motor Driving.* E. Kilburn Scott. (22) Jan. 12.
Cast Iron (in the foundry). Herbert Pilkington. (22) Jan. 12.
Fireclays and Moulding Sands. Percy Longmuir. (Paper read before the British Foundrymen's Assoc.) (22) Jan. 12.
A New Machine for Bending Tests. (14) Jan. 13.
Vertical Retorts for the Production of Illuminating Gas.* W. R. Herring, M. Inst. C. E. (66) Jan. 16.
Shear Stress and Permanent Angular Strain (in turning tools).* W. C. Popplewell, A. M. Inst. C. E. (12) Jan. 19.
A Rational Method of Cooling Gas Engine Cylinders.* S. M. Howell. (46) Jan. 20.
Power Required to Thread, Twist and Split Wrought Iron and Mild Steel Pipe.* T. N. Thomson. (Abstract of Paper read before the Amer. Soc. of Heat. and Vent. Engrs.) (20) Jan. 25; (70) Jan.; (24) Jan. 29.
Some Notes on Modern German Rolling Mills.* (22) Serial beginning Jan. 26.
Superheated Steam.* Michael Longridge, M. Inst. C. E. (Lecture delivered at the Bradford Tech. School.) (47) Serial beginning Jan. 27.
Smoke Abatement: A Report on the London Smoke Abatement Conference: December 13-15, 1905. John B. C. Kershaw. (10) Feb.
Trials of Suction Gas-Producer Plants. (64) Feb.
Applications of Pneumatic Power in the Machine Shop. R. Emerson. (9) Feb.
High Power Gas Engine Electric Plants.* Frank C. Perkins. (41) Feb.
Nickel Steel and Its Application to Boiler Construction. G. B. Waterhouse. (20) Feb. 8.
The Helicoptere: Santos-Dumont's Latest Flying Machine.* L. Ramakers. (46) Feb. 10.
Dampfturbinen mit Geschwindigkeitsstufen und mit Druckstufen. Fritz Krull. (53) Dec. 29.
Die Edison-Portlandzement-Fabrik in Newvillage, New Jersey, V. St. A.* (80) Dec. 30.
Die Bildung von Rissen in Kesselblechen.* C. Bach. (48) Jan. 6.
Die Autogene Schweissung der Metalle. E. Wiss. (48) Jan. 13.
Schwimmender Kohlenspeicher für 12000 t.* W. Kaemmerer. (48) Jan. 27.

**Metallurgical.**

The Effect of Variations in the Speed of Crushing Machinery upon the Production of Undersized Material. H. W. Gartrell. (6) Nov.
Steel Castings and the Constitution of Steel.* Percy Longmuir. (From *Iron Trade Review.*) (22) Dec. 29.
Determination of Carbon in Steel by Direct Ignition with Red Lead. Charles Morris Johnson. (58) Jan.
Die Herstellung von Eisen und Stahl auf Elektrischem Wege.* Albert Neuburger. (52) Serial beginning Nov. 15.
Die Brikettierung der Eisenerze und die Prüfung der Erzziegel. H. Wedding. (50) Serial beginning Jan. 1.
Einiges aus der Metallographischen Praxis.* E. Heyn. (Paper read before The Deutscher Verband für die Materialprüfungen der Technik.) (50) Jan. 1.
Ueber den Gegenwärtigen Stand der Gichtgasreinigung. Meyjes. (Paper read before the Südwestdeutsch-Luxemburgische Eisenhütte.) (50) Jan. 1.

**Mining.**

A Hydraulic-Pneumatic Mine Door Opener.* L. L. Logan. (45) Dec. 29.
Some Electric Installations in European Mines.* Emile Guarini. (45) Dec. 29.

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Fuel Economy at Bituminous Coal Mines in Pennsylvania. C. E. Watts. (58) Jan.
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Track Construction in Mines. Leo Gluck. (Abstract of Paper read before the Illinois Soc. of Engrs. and Surveyors.) (13) Jan. 25.
The Manufacture, Application and Distribution of Electric Cables for Collieries.* George G. L. Preece. (Paper read before the Nat. Assoc. of Colliery Mgrs.) (22) Jan. 26.
Tailing Disposal by Gold Dredges.* J. P. Hutchins. (16) Feb. 3.

**Miscellaneous.**

The Estimation of Costs. A. W. Farnsworth. (From Paper read before the Coventry Eng. Soc.) (14) Feb. 3.

**Municipal.**

County Road Construction: A Topical Discussion. (58) Jan.
Municipal Ownership (electric lighting plant). L. A. Redman. (83) Feb. 1.
The Construction of Pavements in Chicago. J. A. Moore. (From Paper read before the Ill. Soc. of Engrs. and Survs.) (14) Feb. 3.

**Railroad.**

Round-House Framing.* R. D. Coombs, Assoc. M. Am. Soc. C. E. (54) Vol. 55.
The Single-Phase Railway System. Charles F. Scott. (Paper prepared for Amer. St. Ry. Assoc.) (47) Dec. 30.
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Contractors' Locomotives.* J. F. Gairns. (10) Jan.
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The Use of Alternating Current for Heavy Railway Service. B. G. Lamme. (17) Jan. 6.
A Hospital Car for the Southern Pacific Ry. (13) Jan. 11.
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Ten-Wheel Locomotive for Passenger or Freight Service, New York Central.* (40) Jan. 12.
Distribution of Steam Production in a Locomotive Boiler. (Tr. fr. *La Revue Generale.*) (40) Jan. 12.
Some of the Essentials in Locomotive Boiler Design.* D. Van Alstyne. (Paper read before the Northwest Ry. Club.) (40) Jan. 12.
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New Compound Locomotive on the Great Central Railway. Charles Rous-Marten. (12) Jan. 19.

*Illustrated.

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Brakes.* A. L. C. Fell. (Paper read before the Tramways and Light Rys. Assoc.) (73) Serial beginning Jan. 19.
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Die Anlagen der Illinois-Zentral-Eisenbahn in Chikago. Dr. Ing. Blum and E. Giese. (49) Pts. 1-3, 1906.
Schnellzuglokomotive für die Bahn Malmö-Ystad.* A. Doeppner. (48) Jan. 6.
Die Weltausstellung in Lüttich, 1905: Das Eisenbahnwesen, mit Besonderer Berücksichtigung der Lokomotiven. M. Richter. (82) Serial beginning Jan. 6.
Einige Bemerkungen über den Oberbau Amerikanischer Bahnen.* E. Giese. (48) Jan. 20.
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Some Specialties of the System for Flushing the New Sewers of the City of Mexico.* Roberto Gayol, M. Am. Soc. C. E. (54) Vol. 55.
The Scientific Disposal of City Sewage: Historical Development and Present Status of the Problem. C. E. A. Winslow. (7) Dec.
Breakage in Sewer Conduits: Its Cause, Effect and Prevention. Alexander Potter. (1) Dec.
Sizes of Return Pipes in Steam Heating Apparatus. Jas. A. Donnelly. (Paper read before the Amer. Soc. of Heat. and Vent. Engrs.) (70) Jan.; (14) Feb. 3.
Plumbing, Drainage and Water Supply in a Block of Five Apartment Houses, New York.* (70) Jan.
Sewage Purification, with Notes on English and German Works. Charles F. Mebus. (2) Jan.
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Arrangements for the Ventilation of the Debating-Rooms of the New Riksdag's Building in Stockholm, and the Results Obtained in this Respect.* Wilhelm Dahlgren. (70) Jan.
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What Methods are Most Suitable for Disposal of Sewage on the Atlantic Coast? Geo. W. Fuller, M. Am. Soc. C. E. (Address before New Jersey San. Assoc.) (13) Jan. 25.
Present Practice in Sewage Disposal. (14) Jan 27.
Sedimentation: Its Relation to Drainage. J. W. Dappert. (Abstract of Paper read before the Ill. Soc. of Engrs. and Survs.) (13) Feb. 1.
A Test as to the Comparative Efficacy of Upward and Downward Ventilation Systems in the New Riksdag's Building, Stockholm, Sweden. Wilhelm Dahlgren. (Abstract from Paper read before the Amer. Soc. of Heat. and Vent. Engrs.) (13) Feb. 1.
Heating and Ventilating the Main Auditorium of the Broadway Tabernacle, New York City. C. Teran. (Paper read before the Amer. Soc. of Heat. and Vent. Engrs.) (13) Feb. 1; (70) Jan.
The Sewage Disposal Plant at Downers Grove, Ill.* W. S. Shields. (Paper read before the Ill. Soc. of Engrs. and Survs.) (14) Feb. 3; (13) Feb. 8.
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The Theory of Frameworks with Rectangular Panels, and Its Application to Buildings Which Have to Resist Wind. Ernst F. Jonson, Assoc. M. Am. Soc. C. E. (54) Vol. 55.
Theory of the Spherical or Conical Dome of Reinforced Concrete or Metal. William Cain, M. Am. Soc. C. E. (54) Vol. 55.
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Legal Requirements in Regard to Concrete Building Construction. Rudolph P. Miller, M. Am. Soc. C. E. (Abstract of Paper read before the National Assoc. of Cement Users.) (13) Jan. 25.
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Cement and Building Construction.* C. A. P. Turner. (Paper read before the Nat. Assoc. of Cement Users.) (60) Feb.
Concrete Aggregates. Sanford E. Thompson. (Paper read before the Nat. Assoc. of Cement Users.) (14) Jan. 27; (60) Feb.
The Resistance of Cement and Concrete Construction to Fire. (Abstract of Rept. of Com. on Fireproofing and Insurance of Nat. Assoc. of Cement Users.) (13) Feb. 1.
Practical Notes on Concrete Building Construction. C. A. P. Turner, M. Am. Soc. C. E. (Abstract of Paper read before the Nat. Assoc. of Cement Users.) (13) Feb. 1.
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Vol. XXXII. FEBRUARY, 1906. No. 2.

# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## THE PANAMA CANAL.

BY A. G. MENOCAL, M. Am. Soc. C. E.*

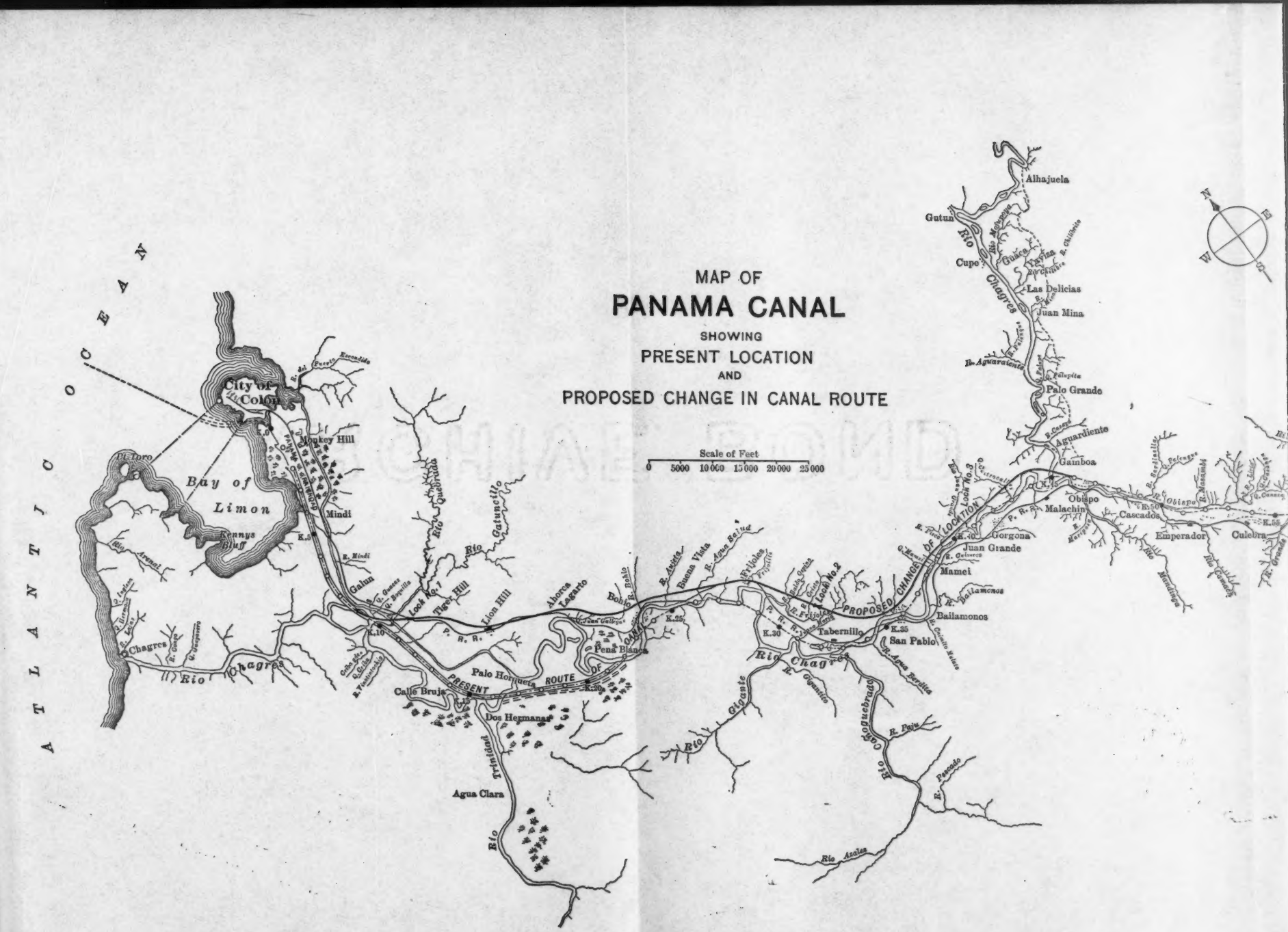
TO BE PRESENTED APRIL 4TH, 1906.

The most difficult engineering problem involved in the construction of a canal at Panama is the control of River Chagres. It enters as an important factor in the design of either a lock or a sea-level canal, and the divergence of opinions, among engineers called upon to decide as to the type of canal best adapted to meet the physical conditions prevailing in the Isthmus, can be traced to the difficulties connected with that river, both as regards the control of the floods, in all types of canal, and the provisions for an ample water supply for operating it during the dry season, in the case of a canal with locks.

It is evident that a lock canal is the most economical type, both in cost and time of construction, and that the sea-level proposition is born either of sentiment or of a belief that by its adoption the difficulties connected with the river can best be overcome. It is well known that a sea-level canal pertaining to the nature of a strait is not possible at Panama. The tidal fluctuation of 20 ft. at the Pacific terminus while the Atlantic end is practically tide-

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* Civil Engineer, U. S. N., *Retired*.


MAP OF
PANAMA CANAL
SHOWING
PRESENT LOCATION
AND
PROPOSED CHANGE IN CANAL ROUTE
Scale of Feet
0 5000 10000 15000 20000 25000
ATLANTIC OCEAN
City of Colon
Monkey Hill
Pt. Toro
Bay of Limon
Mindi
Rennys Bluff
Gatun
Lock No. 1
Tiger Hill
Lion Hill
Rio Gatuncillo
Rio Chagres
Chagres
Palo Hormiga
PRESENT ROUTE OF R. R.
Calle Bruja
Dos Hermanas
Agua Clara
Trinidad
Ahorca Lagarto
Bohio
Pena Blanca
Buena Vista
Frijoles
Lock No. 2
PROPOSED CHANGE OF LOCATION
Tabernillo
San Pablo
Bailamonos
Mamei
Juan Grande
Gorgona
Malachin
Obispo
Cascados
Emperador
Culebra
Gamboa
Aguardiente
Palo Grande
Juan Mina
Las Delicias
Cupe
Gutun
Alhajuela
Rio Gigante
Rio Gogueberado
Rio Pascado
Rio Aguacate
Rio Aguaraleta
Rio Obispo
Rio Chagres

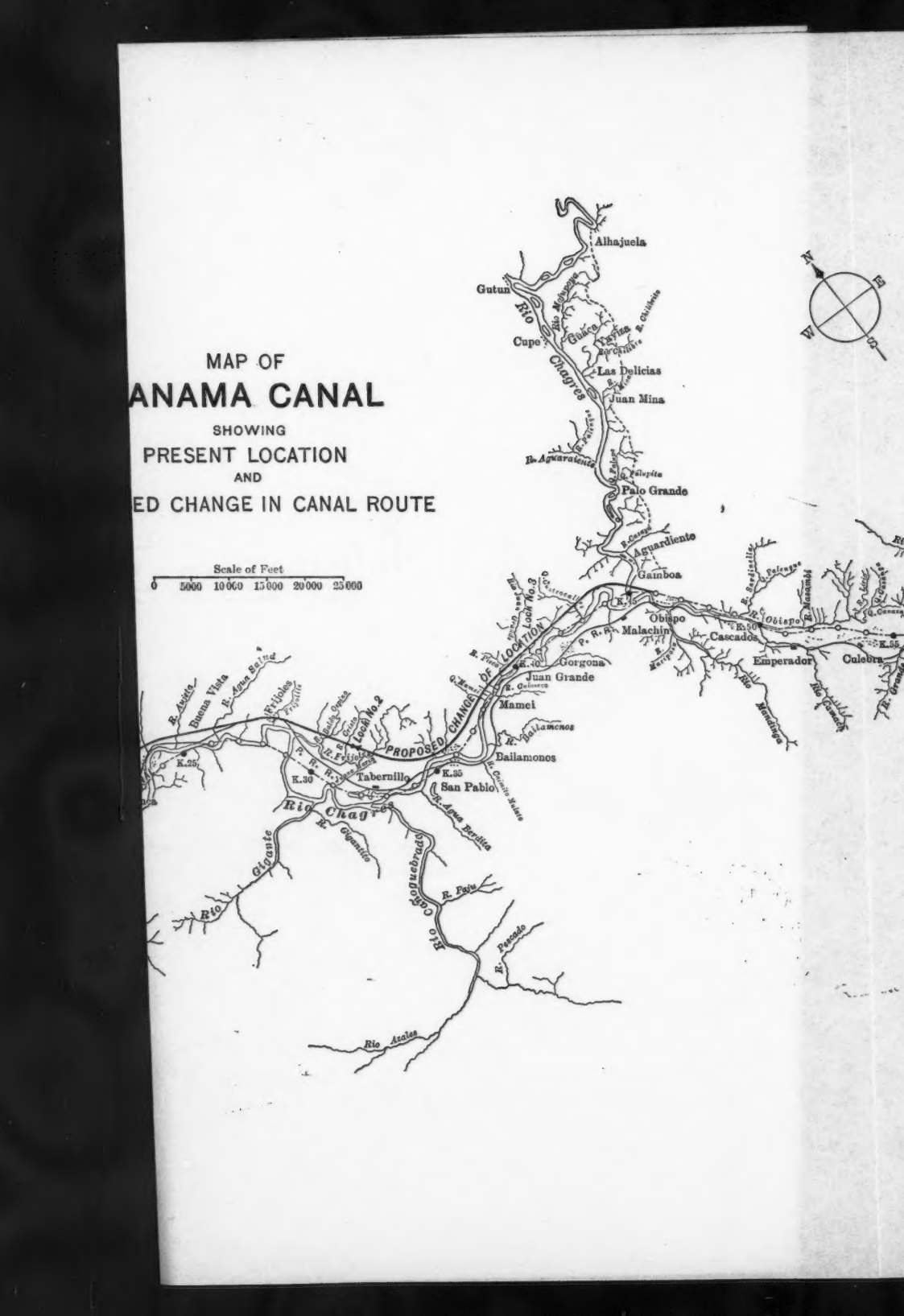
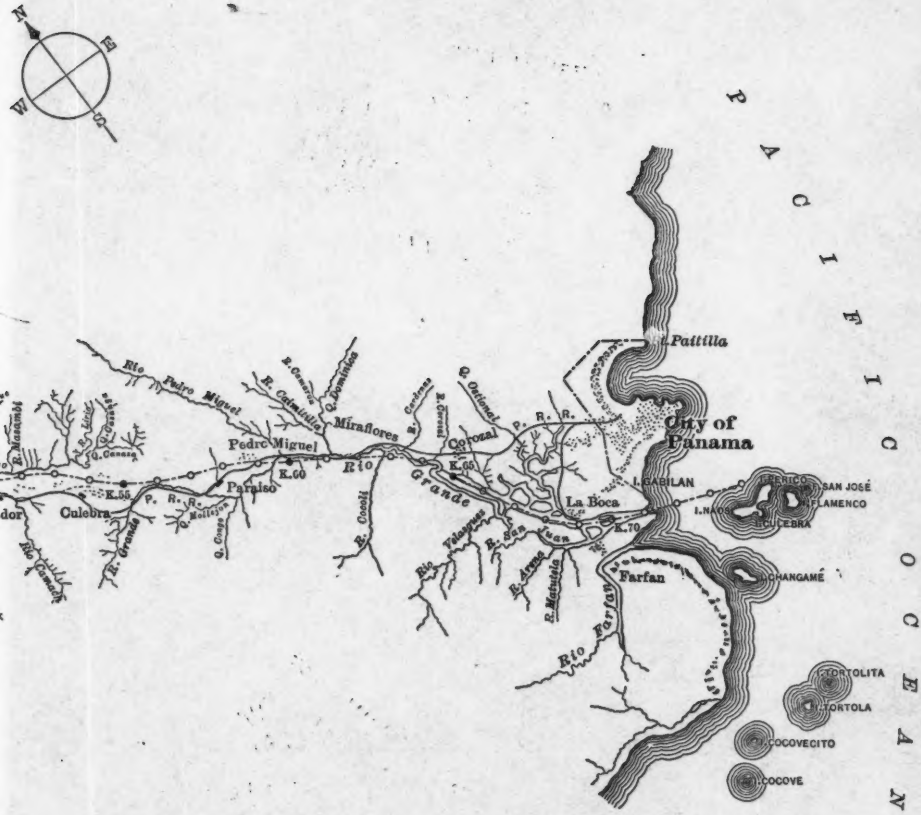

MAP OF
ANAMA CANAL
SHOWING
PRESENT LOCATION
AND
ED CHANGE IN CANAL ROUTE
Scale of Feet
0 5000 10000 15000 20000 25000
N
E
W
S
Alhajuela
Gutun
Rio Chagres
Cupe
Las Delicias
Juan Mina
Palo Grande
Aguardiente
Gamboa
Obispo
Malachin
Cascados
Emperador
Culebra
Gorgona
Juan Grande
Mamei
Dailamonos
Tabernillo
San Pablo
PROPOSED CHANGE OF LOCATION
Locks No. 1
Locks No. 2
Locks No. 3
K.10
K.25
K.30
K.35
K.55
P. R. R.
Rio Chagres
Rio Gigante
Rio Agua Sucia
Rio Pescado
Rio Azules
Rio Mandinga

PLATE I.
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less, makes imperative the introduction of a tide lock at Panama, by which ships can be locked up or down, into or from the canal, depending on the stage of the sea level at the time of taking or leaving the waterway. That tidal lock will limit the number of vessels passing through the canal just as much as a series of locks in a lock canal. Some time will be spent in passing each additional lock introduced, and this should not exceed 30 minutes at each lockage, so that the additional time consumed in passing through a canal with six locks would not be more than 3 hours; an insignificant delay for a ship which has saved thousands of miles by taking the canal route.

Considering, therefore, the cost and time saved in constructing a lock canal, as compared with one at sea level, as well as the elimination of the uncertainties and engineering difficulties connected with the latter, it seems that the former type should be adopted, provided the River Chagres can be effectually controlled, an ample water supply provided, and difficult engineering problems avoided.

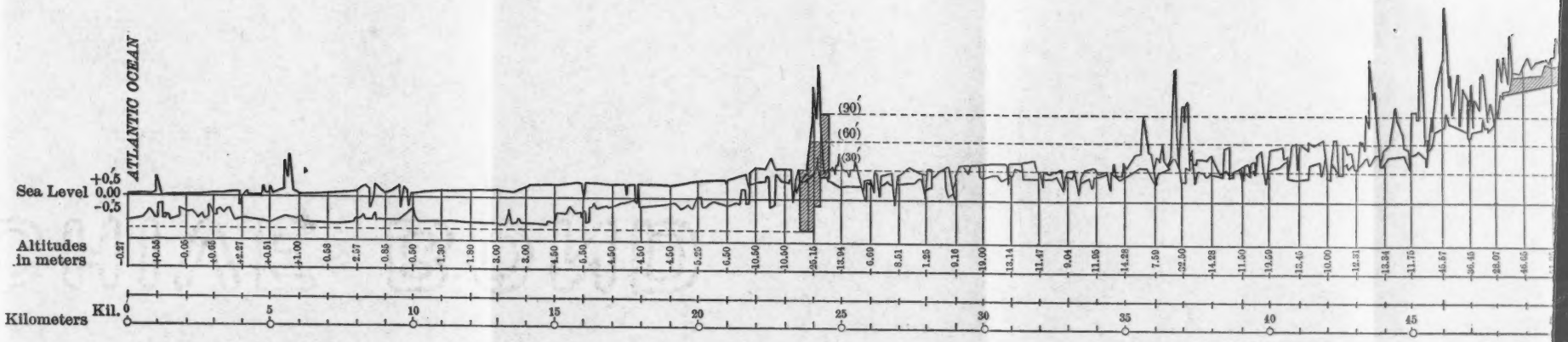
The object of this paper is to submit for discussion by the Society a modification of the canal route recommended by the Isthmian Canal Commission of 1899-1901 for a lock canal, by which the River Chagres may be kept under absolute control, its channel being left free to carry off the floods, an abundant supply of water close at hand secured for the operations of the canal, all doubtful problems eliminated, without increasing the cost estimated by the Commission, and with a saving of time in the execution of the work. The change in location recommended begins at Kilometer 46, just south of where the present location meets the Chagres River. On a prolongation of the tangent ending at this point it crosses the River Chagres in the vicinity of Gamboa, and thence, upon the line located by the United States Surveying Expedition of 1875, the canal is kept north of the river, meeting the present location again at Kilometer 9 and coinciding with it to the Harbor of Colon. (Plate I.)

The crossing of the Chagres is proposed to be accomplished by means of a combined dam, viaduct, and controlling works. The dam impounds the river at a maximum elevation of 111 ft. above mean sea level and a minimum of 106 ft. at the end of the dry season.

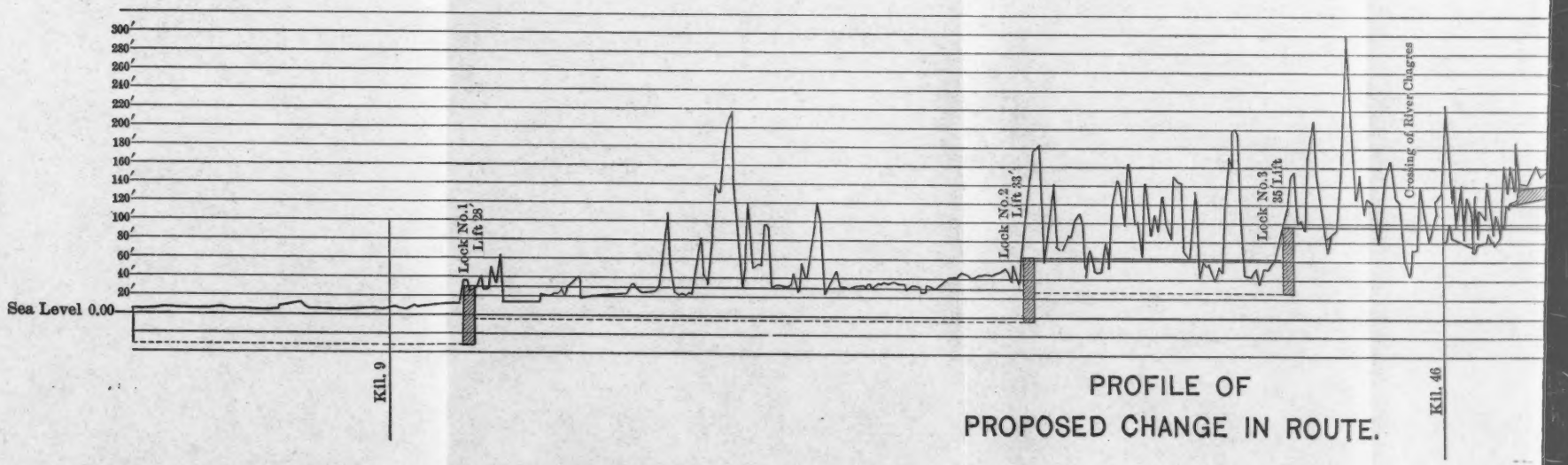
The canal crosses the river in a viaduct, which is also part of the dam, with a summit elevation of 96 ft., the bottom width being 150 ft., and the depth of water 35 ft. As the minimum elevation of the lake formed by the dam is estimated to be at no time lower than 106, the canal can be supplied with the water needed for its operation by short pipes passing through the dam and discharging under the water surface. The water supply is thus kept under perfect control, to be drawn as needed, and the canal can be maintained at a uniform level.

The river controlling works consist of seven compartments or gate-wells (see Plates III and IV) and twenty-one 10-ft. metal-lined sluices passing through the structure. These sluices are provided with gates, three in each compartment, operated from the upper platform, by which the river flow can be completely shut off, which may be desirable in the dry season when the river flow may, at times, be less than that required for operating the canal; or the gates may be partially or entirely opened to allow the free passage of floods. With the water in the lake at an elevation of 111 and the lower river in flood, 30 ft. above low water at the viaduct, the twenty-one sluices, under such extreme conditions, will be capable of passing 78 000 cu. ft. per sec., which is far in excess of any known flood discharge at Gamboa. Gate-wells are provided with sill walls rising 10 ft. above low water in the river, intended to arrest any heavy silt or stones rolling on the river bottom. Above the sill walls, the intakes are provided with grooves for the insertion of movable gates, which can be lowered into place or taken up by derricks in the upper platform. With these gates the intakes can be closed and the water drained from a well for examination or repair when needed.

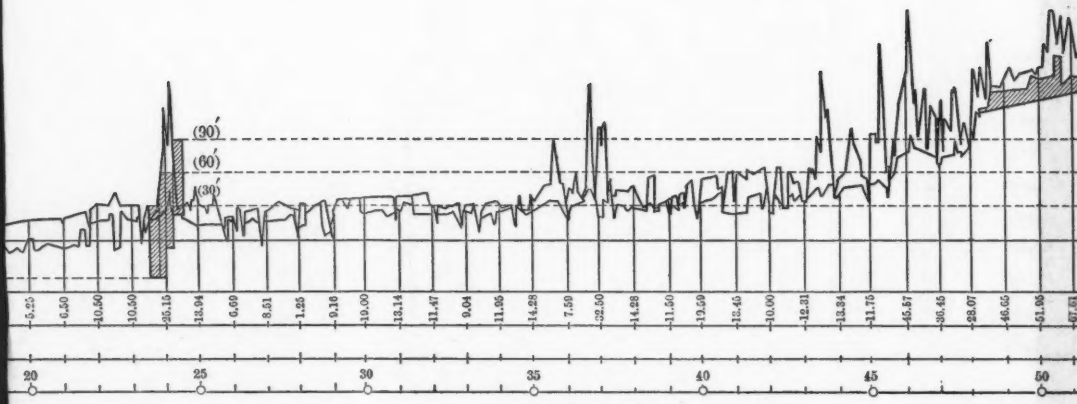
The intakes are protected by heavy iron gratings with openings 2 ft. square to intercept snags, or other floating debris brought down by floods, which might obstruct the sluices or impede the operation of the gates. The water for operating the canal is taken from below the surface of the lake, after passing through the grating, and should be practically free from floating debris. It is discharged into the canal below the surface, so as to cause the least disturbance, or it may be made to discharge through conduits under the bottom of the canal. The upper platform, formed by the dams



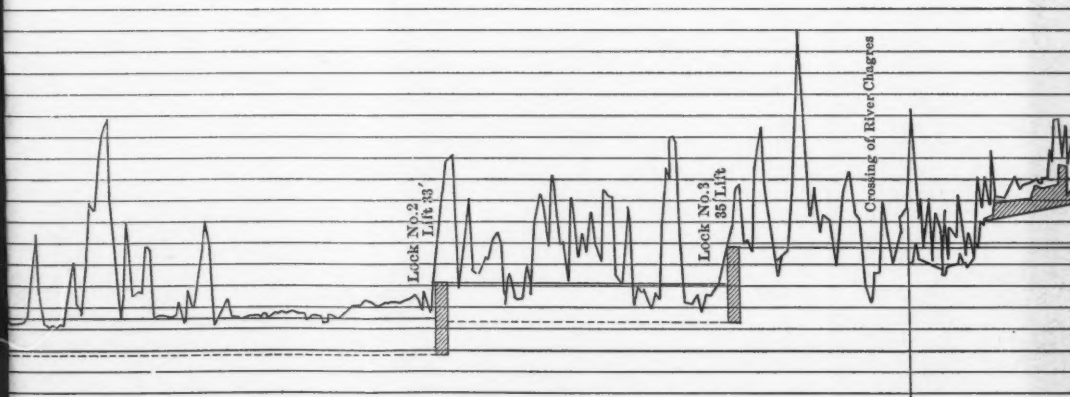

PROFILE OF
PRESENT ROUTE OF CANAL.




PROFILE OF
PROPOSED CHANGE IN ROUTE.

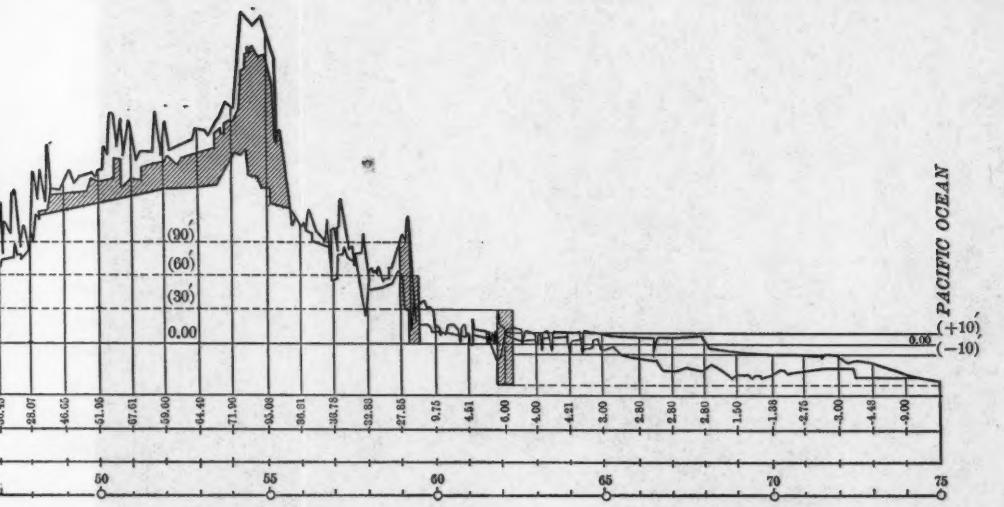


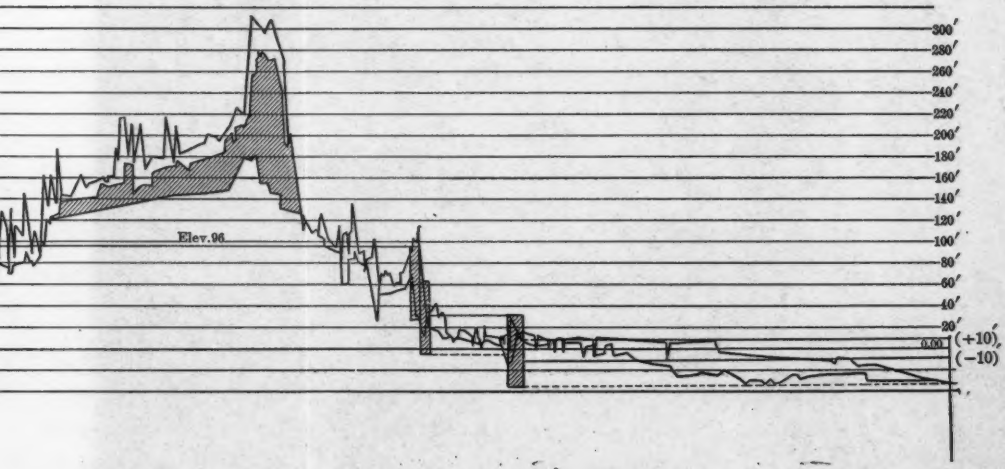

PROFILE OF
PRESENT ROUTE OF CANAL.




PROFILE OF
PROPOSED CHANGE IN ROUTE.

PLATE II.
PAPERS, AM. SOC. C. E.
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MENOCAL ON
THE PANAMA CANAL.



and intake walls, 32 ft. wide, can be roofed for the protection of the gate-operating machinery and the employees manipulating it. The control of the floods and of the water supply can thus be concentrated in one structure.

The combined structure, of reinforced concrete, 232 ft. wide and resting on hard rock, with an elevation of only 118 ft. above the foundations, possesses superabundance of strength and all the conditions of stability and durability essential in a work of this kind. It is believed that it solves effectually the difficult problems connected with the Chagres River, and removes the risks and uncertainties involved in the construction and permanency of dams designed to rest on doubtful foundations. It simplifies the building of the canal, reducing it to a comparatively ordinary engineering work of construction, admitting of an estimate of the cost and time of execution not to be upset by river floods.

The rock surface under the proposed structure has been plotted from data obtained recently by numerous borings made by the engineers of the Isthmian Canal Commission in the vicinity of Gamboa while exploring for the location of a high dam.

The line proposed from Kilometer 9 to Kilometer 46 of the present canal location was surveyed by the United States Government's Surveying Expedition of 1875 under the direction of the writer as Chief Engineer. It is, however, but a trial location which a limited appropriation did not permit to be surveyed in detail. A final location, after careful development of the topography, will, doubtless, bring about important improvements tending to reduce the excavation and the amount of curvature. It is perfectly practical as now laid down, is about a mile shorter than the present canal location between Kilometers 9 and 46, and involves no engineering difficulties of execution.

With good rock foundations and a wide cross-section of the river at the point of crossing, the viaduct-dam can be constructed with the use of coffer-dams in that portion of the work resting on foundations below water level. The summit level of the canal has been placed at Elevation 96, not imposed by the conditions of the problem, but because that is believed to be the most economical elevation. It is evident that, by lowering the sluices, either by reducing their diameter, increasing their number, if necessary, or

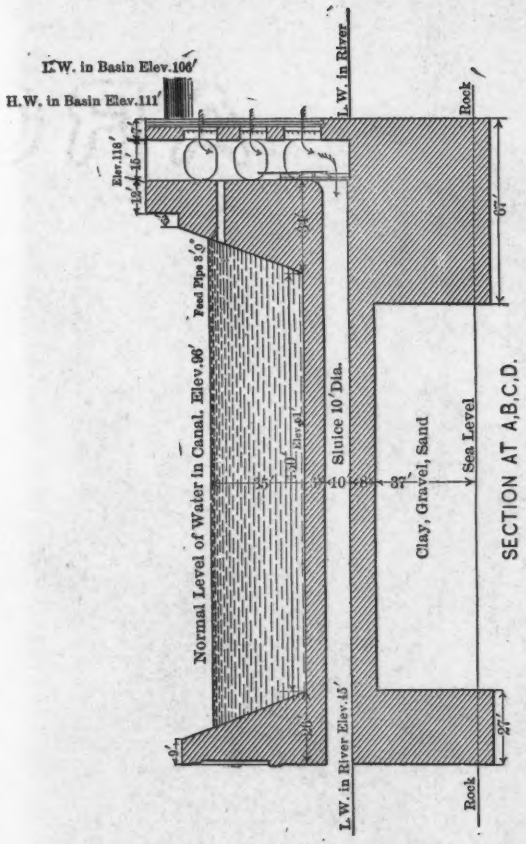
by giving them the shape of inverted siphons, the canal upper level can be lowered several feet, but such modification is not regarded favorably. It would reduce somewhat the lift of the upper locks, which, as herein suggested, is moderate, but at an unwarranted additional cost of excavation.

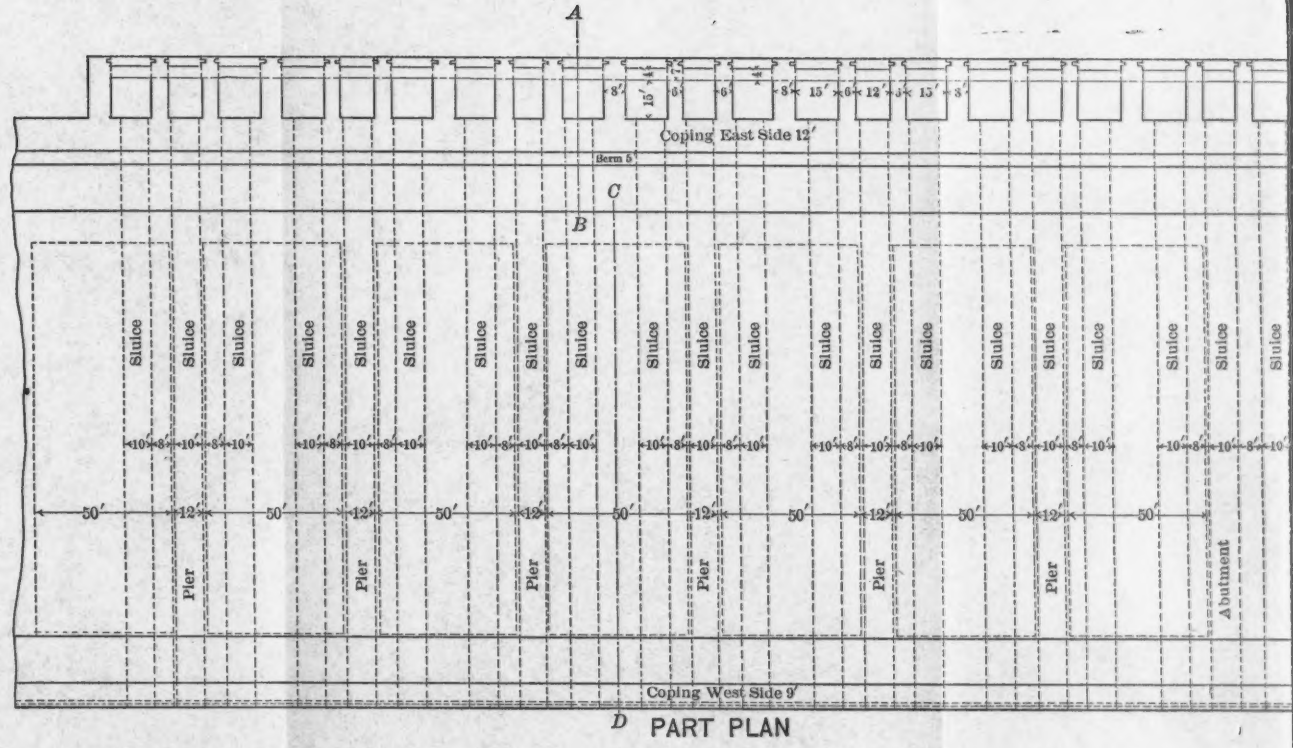
An alternative plan, which has received consideration, consists in bringing the canal into the lake created by the dam and then crossing the river through the lake instead of the viaduct. By such a change of plan, the proposed works would be reduced to the dam and controlling works, and the cost thereby considerably diminished. The writer is of the opinion that such a modification of the scheme is not desirable. The saving in the cost of the structure would probably be more than offset by an increase in excavation; and cross-currents in the lake, fluctuations of level in the canal, and floating objects brought down by river floods would be serious obstacles to navigation, from which the viaduct plan is entirely free.

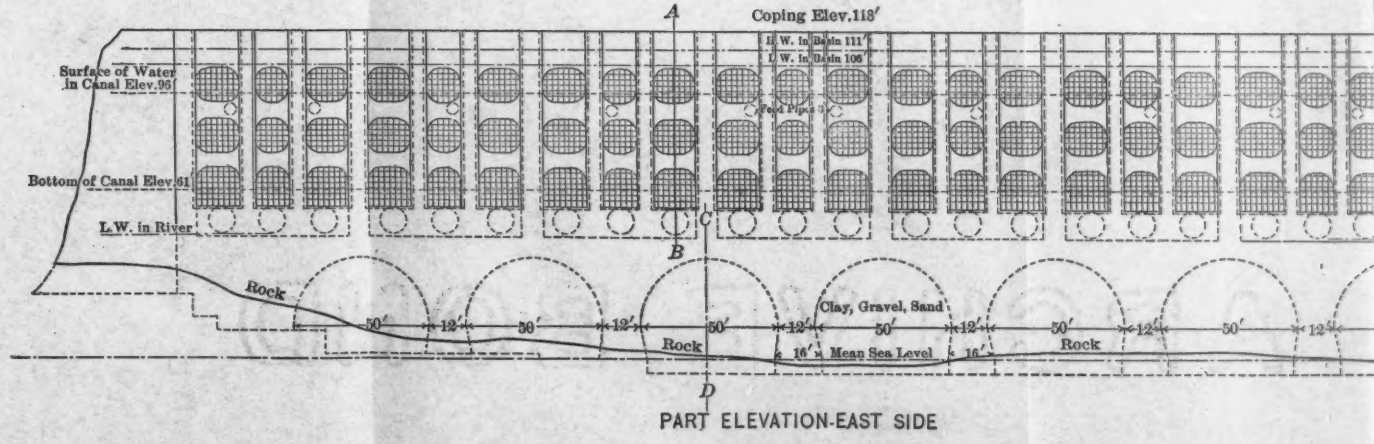
Without a contour map of the river basin above Gamboa, the writer is unable to ascertain the superficial area of the lake created by the dam. With a surface elevation of 111 ft. at the dam, the lake would extend to beyond Alhajuela, where the low-water level will be raised about 8 ft. Considering the broad expansions of the river basin and the re-entering valleys of its tributaries, it is contended that the lake will have an area large enough to receive the greatest floods, without violent fluctuations of level, while the whole flow is being carried off by the sluices, and will have ample storage capacity for an abundant water supply for operating the canal in the dry season within the range of Elevations 106 and 111. No reservoir is needed for the storage of floods, and the precise elevations within which the water supply can be assured is a matter of detail which does not alter the essential features of the proposed scheme.

Pending a resurvey of the new location proposed between Kilometers 9 and 46 (which will doubtless result in material improvement in alignment and elevation), and the borings necessary for a classification of the material to be removed, it is not possible to obtain a close estimate of cost of the modified plans.

However, taking for comparison the estimated cost of the



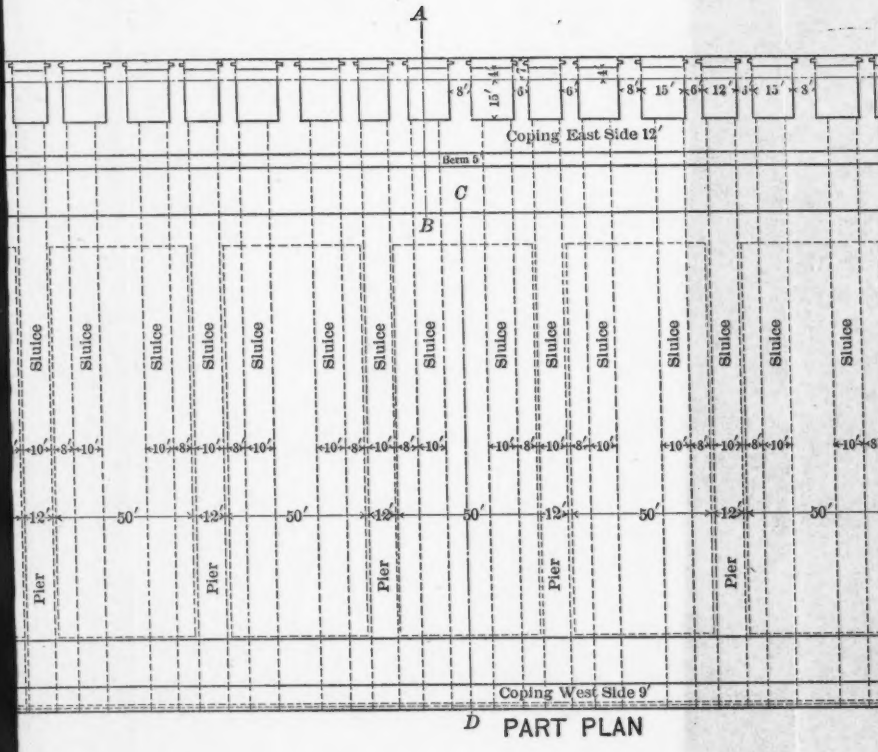



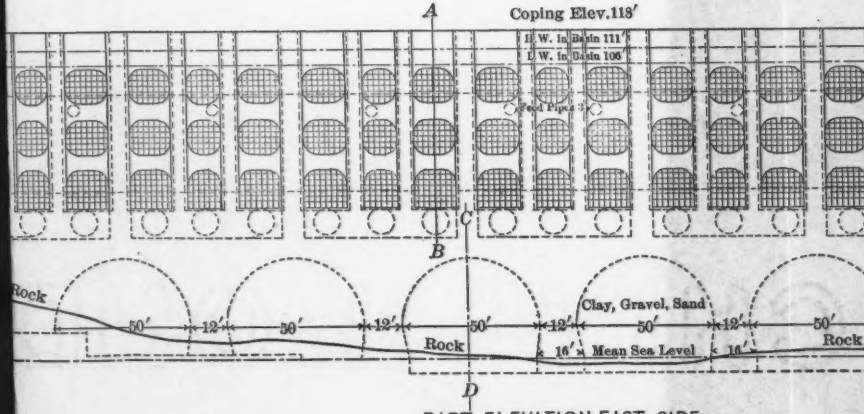

# PANAMA CANAL

## CROSSING OF CHAGRES RIVER

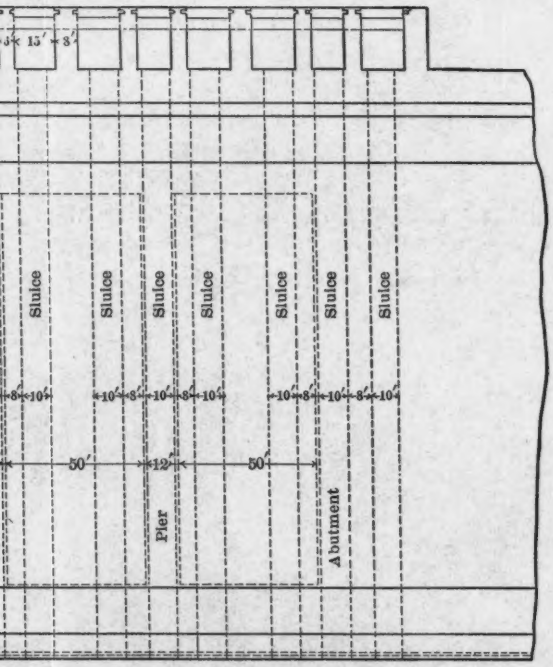
## VIADUCT-DAM-CONTROLLING WORKS.

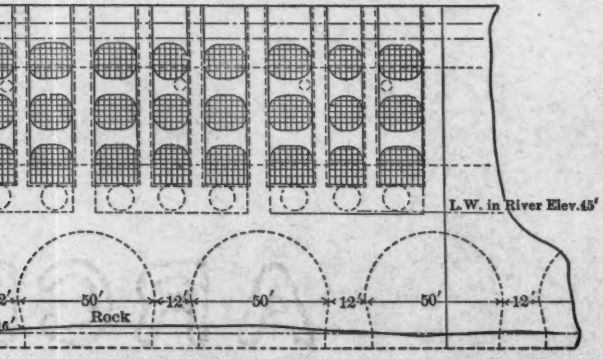



PART PLAN




PART ELEVATION-EAST SIDE


15′
8′
Sluice
Sluice
Sluice
Sluice
Sluice
Sluice
Sluice
8′
10′
10′
8′
10′
8′
10′
10′
8′
10′
8′
10′
50′
12′
50′
Pier
Abutment


L. W. in River Elev. 45′
50′
12′
50′
12′
50′
12′
Rock

Isthmian Canal Commission's plan for a lock canal with a fluctuating summit level between a maximum of 92.5 ft. and a minimum of 82 ft. above mean sea level, it is possible to arrive at the conclusion that the cost of the modified plan proposed will not exceed the estimate of the Commission, and may fall considerably below it. In any case, it is claimed that if the time of construction can be lessened, and the permanency of the canal at a reduced cost of maintenance can be assured, this would be worth several millions.

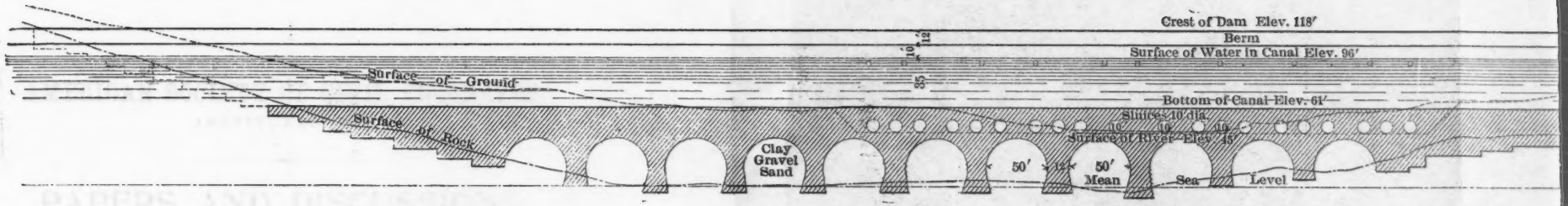
The works of the Chagres crossing are estimated to cost $5 275 000. Upon the new route proposed about 52 000 000 cu. yd. will have to be removed from the Harbor of Colon to Kilometer 46, of which 10 000 000 cu. yd. are contained in the sea-level section from the Harbor to Kilometer 9, where it joins the new line. The latter quantity is probably material which can be dredged, the other 42 000 000 cu. yd. being dry soil with some rock in the high ridges crossed.

To offset the cost of these works, the following amounts are taken from the estimate of the Commission for work between Colon and Kilometer 45, which would be eliminated by the adoption of the modified plan.

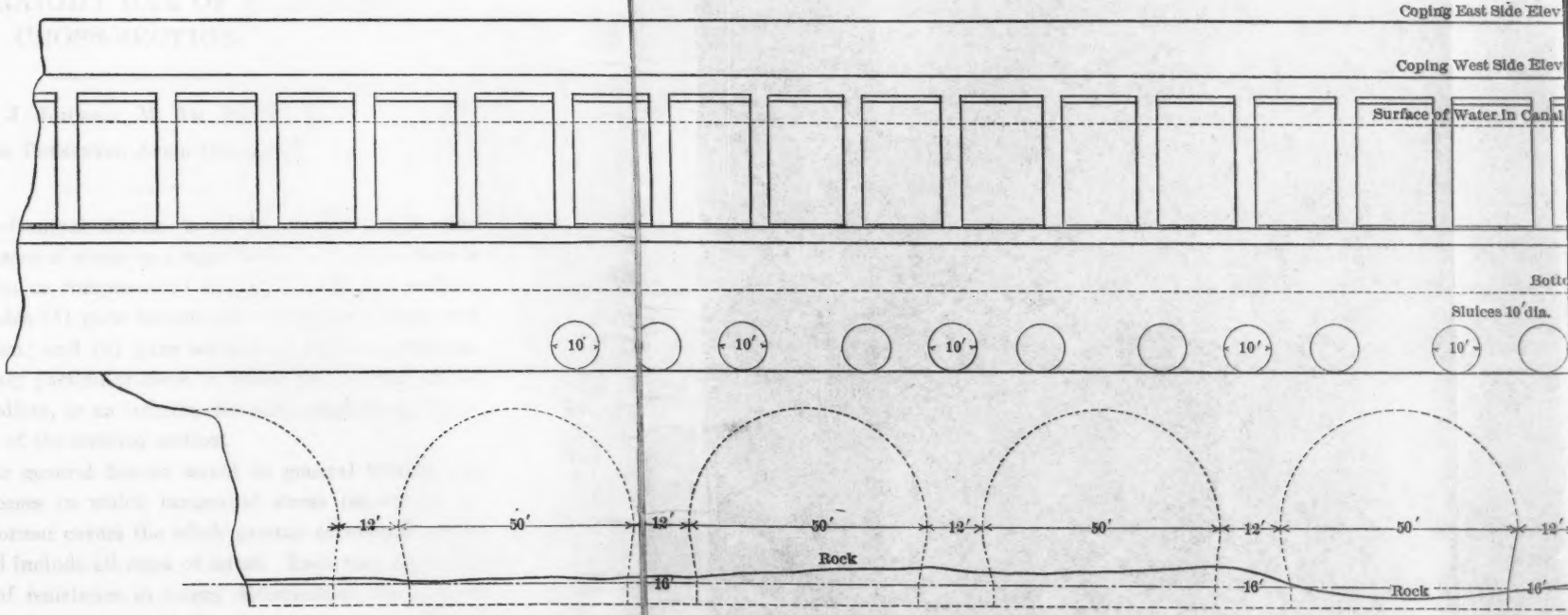
| | |
|---|---|
| Harbor of Colon to Bohio Locks, including levees | $11 099 839 |
| Lake Bohio | 2 952 154 |
| Obispo Gates | 295 434 |
| Bohio Dam | 6 369 640 |
| Gigante Spillway | 2 448 076 |
| Pena Blanca Outlet | 1 999 982 |
| Diversion of the Panama Railroad | 1 267 500 |
| Total | $26 432 625 |

In addition to this total, there would also be a saving of 14 ft. depth in the Culebra Cut, by raising the bottom of the canal from Elevation 47 to Elevation 61, which may be estimated to contain about 20 000 000 cu. yd. The item, $11 567 275, in the Commission's estimate for the two high-lift locks at Bohio will probably balance the cost of the three locks of about the same aggregate lift proposed on the new route now suggested.

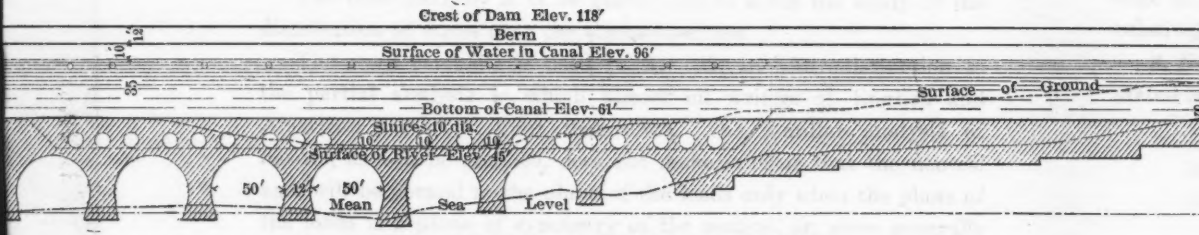
As the basin of the Chagres below Gamboa is not to be flooded by the creation of a lake, the diversion of the Panama Railroad becomes unnecessary. The road can cross the canal by drawbridges, or under it by short tunnels where necessary, and, eventually it can be built on the berm of the canal if so desired.



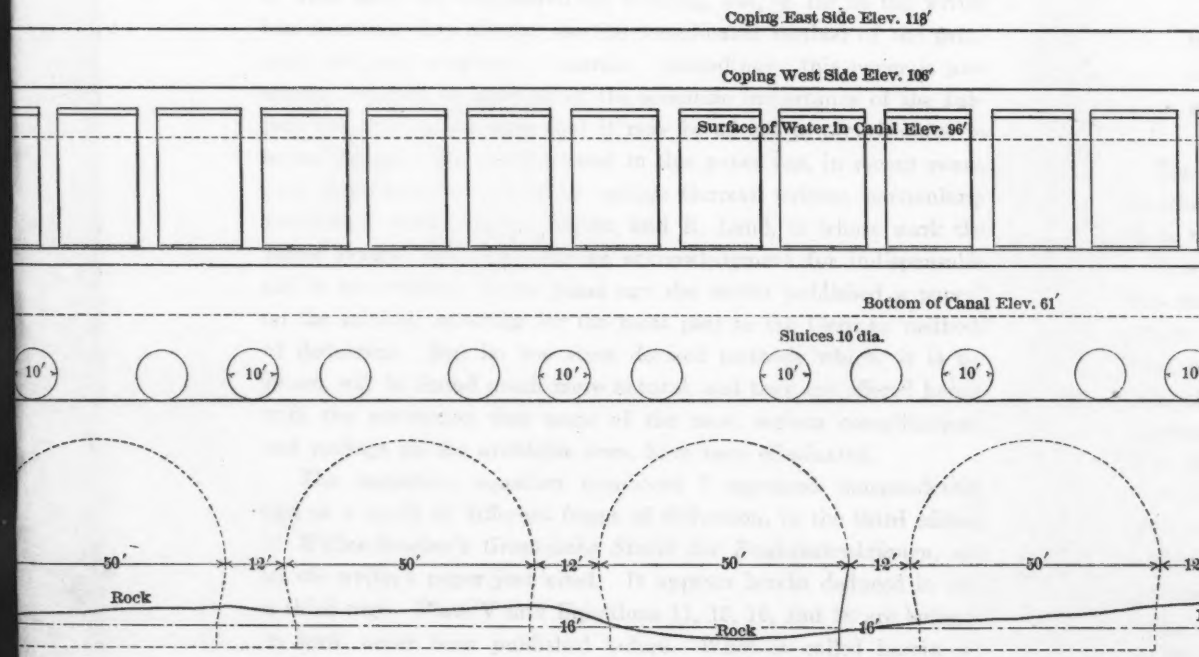

LONGITUDINAL SECTION THROUGH AXIS OF CANAL.




PART ELEVATION—WES

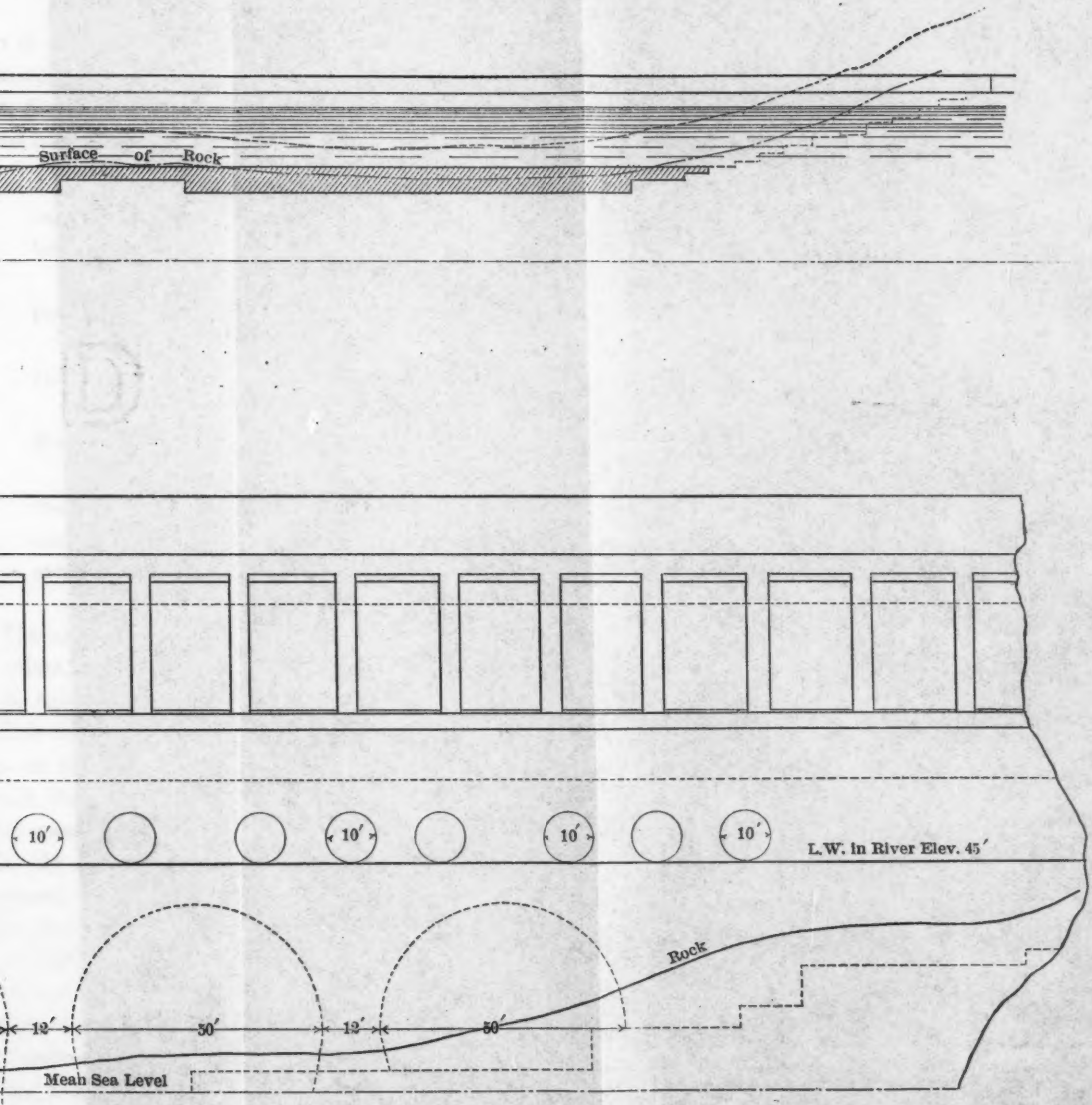



LONGITUDINAL SECTION THROUGH AXIS OF CANAL




PART ELEVATION—WEST SIDE

PLATE IV.
PAPERS, AM. SOC. C. E.
FEBRUARY, 1906.
MENOCAL ON
THE PANAMA CANAL.



Vol. XXXII. FEBRUARY, 1906. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## A COMPLETE ANALYSIS OF GENERAL FLEXURE IN A STRAIGHT BAR OF UNIFORM CROSS-SECTION.

By L. J. Johnson, M. Am. Soc. C. E.

To be Presented April 18th, 1906.

*1. Introduction.*—General flexure is to be understood in this paper to include all cases of stress in a right section in which there is normal stress (tension or compression) in any part of the section. Accordingly, it includes (1) pure flexure; (2) combined flexure, and tension or compression; and (3) pure tension or pure compression. These three are merely particular cases in which the neutral axis is at a zero, an intermediate, or an infinite, distance, respectively, from the center of gravity of the stressed section.

The correlative to general flexure would be general torsion, the latter covering all cases in which tangential stress (shear) is involved, just as the former covers the whole ground of normal stress. Together, they would include all cases of stress. Each may be looked upon as the result of resistance to rotary deformation, the axis of rotation being, in the former case, in the plane of the stressed section, in the latter, normal to that plane.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The term analysis is to be understood to mean the study of the distribution of stress over the stressed section.

The word complete is used in the title in contradistinction to the partial analysis to which almost all writers of English and American textbooks limit themselves. The familiar analysis of flexure, as will be recalled, does not make it clear that the neutral axis will be normal to the plane of the loads only when the plane of the loads is a plane of symmetry of the section, or, more generally speaking, includes a principal axis of inertia of the section. To be sure, this condition does obtain in most cases in practice, but by no means in all, and errors have crept into some of our best books on structural design from a failure to realize the limitations of the familiar analysis. Occasional writers devote a moment's attention to what they call unsymmetrical bending, but, as far as the writer has observed, they always use the complicated method of the principal axes and moments of inertia. Accordingly, this paper is presented, not only on account of the scientific importance of the subject, but also in the hope that it may be of use to practitioners in actual design. The topic treated in this paper has, in recent years, been given much attention by various German writers, particularly Professors Müller-Breslau, Mohr, and R. Land, to whose work the writer renders most appreciative acknowledgment for indispensable aid in his studies. Some years ago the writer published a paper* on the subject, adhering for the most part to the German methods of deduction. But he has since devised methods which, it is believed, will be found much more natural, and they are offered herein with the conviction that some of the most serious complications, and perhaps all the avoidable ones, have been eliminated.

The important equation numbered 7 appeared independently, and as a result of different forms of deduction, in the third edition of Müller-Breslau's *Graphische Statik der Baukonstruktionen,* and in the writer's paper just cited. It appears herein deduced in still a third way. Plate V and Equations 11, 15, 16, and 18 are believed to have never been published before. What is called herein the $S$-polygon (perhaps the most useful of the results) is a modification of Land's "$W$-Fläche."

Sections 2 to 8 include all that is essential for a working knowl-

* *Journal* of the Association of Engineering Societies, May, 1902.

edge of the subject. Sections 9 to 11 contain tributary matter of a relatively academic nature.

*2. Statement of the Problem.*—The problem to be solved may be stated in precise terms as follows:

> *Given:* A straight bar of uniform section subject to loads in any plane which includes the longitudinal axis of the body.*
>
> *Required:* I. The intensity of the normal stress at any point of a given right section;
>
> II. The extreme values of the normal stress intensity (called commonly extreme fiber stresses) in the given section;
>
> III. Quick practical means for computing these extreme fiber stresses in all cases;
>
> IV. Similar means, if possible, for indicating which of the familiar rolled-steel sections is to be selected to resist any case of general flexure in order to keep the extreme fiber stresses within prescribed limits.

The satisfaction of the first requirement will clear the way for the others. The latter, though, mathematically, corollaries to the first, are to the practitioner of paramount importance.

It is to be understood that the section of the body may or may not have an axis of symmetry, and that the forces are not too great to permit the usual assumption of linear distribution of stress. Extreme cases of irregularity of cross-section, which would interfere with the applicability of this assumption, might, perhaps, be imagined, but no section likely to be used in practice is believed to be of this sort.

*3. Outline of Method of Procedure.*—The external forces on the whole bar being in equilibrium, the force transmitted past the given section of the bar is the resultant, $R$, of all the forces on one side of the section—an equal, opposite and coincident resultant coming, of course, from the other side and together producing at the same time equilibrium of the body, and stress at the section.

---

*This limitation of the location of the loads eliminates torsion—a stress which would not affect the problem, should it exist—and thus helps to fix ideas at the outset.

If the given forces should not be in a plane, as just limited, general flexure would be due only to their components in such a plane, and only such components would enter the problem. The above statement of the data, therefore, is actually general in spite of appearances to the contrary.

Suppose (Fig. 1) the point where $R$ intersects the plane of the section be called $K$, distant $q$ from the center of gravity, $G$, of the section. $R$ may be resolved into two components at $K$, one normal to the section, the other tangential and passing through $G$. Only the former affects the problem; and it alone, under the designation, $N$, will henceforth be considered.

Statically speaking, the problem is to resolve $N$ into an infinite number of non-co-planar parallel forces. Pure statics being unequal to the task, the necessary aid is found in the principle of linear distribution of stress, a principle now universally accepted as valid for moderately loaded beams of wood and metal. Stating this prin-

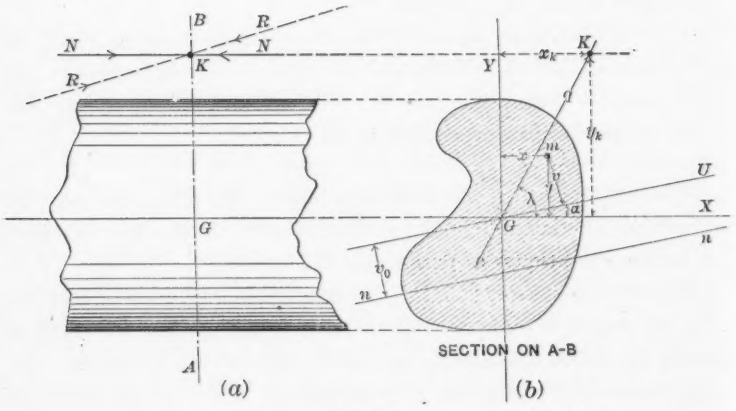



FIG. 1.

ciple and the conditions of equilibrium in algebraic language, there result four simultaneous equations, the solution of which yields the required quantity, stated in terms of the given quantities. This solution once obtained, it will receive further study, with a view to facilitating its application.

*4.—Algebraic Statement of the Conditions.*—Let the beam have any section, as that of Fig 1(*b*), referred to any convenient pair of rectangular axes, $G\ X$ and $G\ Y$, the origin, $G$, being the center of gravity of the section. Let $f$ be the required stress-intensity at $m$, any infinitesimal portion of the section, distant $x$ and $y$ from $G\ Y$

and $G\ X$, respectively. The point, $K$, the co-ordinates of which will be called $x_k$, $y_k$, being, as above stated, the intersection of $R$ with the section, and distant $q$ from $G$, call $\lambda$ the inclination of $G\ K$ to $G\ X$. Let $n\ n$ be the locus of points where $f$ is zero (that is, the neutral axis) inclined to $G\ X$ by the angle, $\alpha$. $G\ U$ is a line drawn through $G$ parallel to $n\ n$. The distance between $n\ n$ and $G\ U$ will be called $v_o$.

The algebraic statement of the principle of linear distribution may conveniently be written

$$f = f_o - \frac{f_o}{v_o} v,$$

in which $f_o$ is the constant value of $f$ at all points of $G\ U$, and $v$ is the distance of $m$ from $G\ U$. The lengths, $v$ and $v_o$, are + or — according as they are measured from $G\ U$ toward or away from $K$. Accordingly, $f_o$ and $\frac{f_o}{v_o}$ are placed in the equation with opposite signs, and + is selected for the former. Then, as will be seen from Equation 8, a positive result for $f$ will indicate that the stress at $m$ is of the same sign as if $N$ were applied at $G$, and *vice versa*. Referring $m$ to $G\ X$ and $G\ Y$, by substituting $y \cos. \alpha - x \sin. \alpha$ for $v$, the equation becomes

$$f = f_o - \frac{f_o}{v_o} (y \cos. \alpha - x \sin. \alpha) \ldots\ldots\ldots\ldots\ldots (1)$$

Here, $f_o$, $v_o$, and $\alpha$ are unknowns, and three more equations are required for their evaluation. The conditions of equilibrium are now brought into use.

Expressing the infinitesimal area, $m$, as $d\ x\ d\ y$, an unbalanced single force will be precluded under the conditions if

$$\int\int f\, dx\, dy = N \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

and, similarly, an unbalanced couple will be precluded if

$$\int\int x f\, dx\, dy = N x_k \ldots\ldots\ldots\ldots\ldots (3)$$

and

$$\int\int y f\, dx\, dy = N y_k \ldots\ldots\ldots\ldots\ldots (4)$$

With these three equations the unknowns can be eliminated from Equation 1, and the expression for $f$ will be left in proper shape for discussion and use.

5. *Deduction of the Desired Equations.*—Substituting* the value of $f$ from Equation 1 in each of the Equations 2, 3 and 4, and noting that

$$\int\int dx\,dy = A, \text{ the area of the section,}$$

$$\int\int x\,dx\,dy = 0, \text{ since } G\,Y \text{ is a gravity axis,}$$

$$\int\int y\,dx\,dy = 0, \text{ since } G\,X \text{ is a gravity axis,}$$

$$\int\int y^2\,dx\,dy = I_x\dagger, \text{ the moment of inertia of the section referred to } G\,X,$$

$$\int\int x^2\,dx\,dy = I_y\dagger, \text{ the moment of inertia of the section referred to } G\,Y,$$

$$\int\int xy\,dx\,dy = J\dagger, \text{ the product of inertia of the section referred to } G\,X \text{ and } G\,Y.$$

---

* This substitution being a highly important step, the algebraic reduction is stated as follows:

Equation 2, with $f_o - \frac{f_o}{v_o}(y\cos.\,\alpha - x\sin.\,\alpha)$ substituted for $f$, becomes

$$\int\int \left\{f_o - \frac{f_o}{v_o}(y\cos.\,\alpha - x\sin.\,\alpha)\right\} dx\,dy = N,$$

that is,

$$f_o\int\int dx\,dy - \frac{f_o}{v_o}\cos.\,\alpha\int\int y\,dx\,dy + \frac{f_o}{v_o}\sin.\,\alpha\int\int x\,dx\,dy = N.$$

Inserting values of the integrals stated above, this becomes

$$A\,f_o = N,$$

whence Equation 5.

Equation 3, upon substitution of $f_o - \frac{f_o}{v_o}(y\cos.\,\alpha - x\sin.\,\alpha)$ for $f$, becomes

$$\int\int \left\{f_o - \frac{f_o}{v_o}(y\cos.\,\alpha - x\sin.\,\alpha)\right\} x\,dx\,dy = N\,x_k,$$

that is,

$$f_o\int\int x\,dx\,dy - \frac{f_o}{v_o}\cos.\,\alpha\int\int xy\,dx\,dy + \frac{f_o}{v_o}\sin.\,\alpha\int\int x^2\,dx\,dy = N\,x_k.$$

Inserting the stated values of the integrals as before, this becomes

$$-\frac{f_o\,J\cos.\,\alpha}{v_o} + \frac{f_o\,I_y}{v_o}\sin.\,\alpha = N\,x_k,$$

or

$$-\frac{f_o}{v_o}(J\cos.\,\alpha - I_y\sin.\,\alpha) = N\,x_k,$$

whence

$$-\frac{f_o}{v_o} = \frac{N\,x_k}{J\cos.\,\alpha - I_y\sin.\,\alpha}, \text{ which is part of Equation 6.}$$

Similarly, by substituting Equation 1 in Equation 4 it falls out that

$$-\frac{f_o}{v_o} = \frac{N y_k}{I_x\cos.\,\alpha - J\sin.\,\alpha},$$

which completes Equation 6.

† Computation of $I_x$, $I_y$, and $J$.—The computation of $I_x$ and $I_y$ involves, in practice, only the application of the familiar, $I' = I_o + A\,h^2$. For all the structural shapes, the

it will appear that

$$f_o = \frac{N}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

(showing that the unit stress at the center of gravity is always the same as it would be if $N$ were applied there), and that

$$-\frac{f_o}{v_o} = \frac{N x_k}{J \cos.\ \alpha - I_y \sin.\ \alpha} = \frac{N y_k}{I_x \cos.\ \alpha - J \sin.\ \alpha} \quad \ldots\ldots\ldots (6)$$

Solving Equation 6 yields, noting that $\frac{y_k}{x_k} = \tan.\ \lambda$,

$$\left.\begin{aligned} \tan.\ \alpha &= \frac{I_x - J \tan.\ \lambda}{J - I_y \tan.\ \lambda} \\ &= \frac{I_x \cot.\ \lambda - J}{J \cot.\ \lambda - I_y} \\ &= \frac{I_x \cos.\ \lambda - J \sin.\ \lambda}{J \cos.\ \lambda - I_y \sin.\ \lambda} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (7)$$

the various forms of the second member being convenient in special cases. The first two are usually the simplest to use, but either may become indeterminate on the substitution of special values of $\lambda$. If one of these fails in this way, the other or the third can be used.

Substituting Equations 5 and 6 in Equation 1, there results

$$f = \frac{N}{A} + \frac{N x_k (y - x \tan.\ \alpha)}{J - I_y \tan.\ \alpha} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

or

$$f = \frac{N}{A} + \frac{N y_k (y - x \tan.\ \alpha)}{I_x - J \tan.\ \alpha} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

Equations 8 and 9, if written in terms of $q$, will express $f$ as the result of combining two quantities which represent, respectively, the contributions to $f$ from a force, $N$, at $G$, and the couple, $Nq$, that is, from a force and couple into which any $N$ at $K$ can be resolved.

---

$I_x$ and $I_y$ are given outright by the handbooks. $J$ is not so familiar a quantity and is not mentioned by the handbooks, yet its computation in practical cases is very easy. From the nature of its definition,

$$J = \int\int x\, y\ d\, x\ d\, y,$$

it is evident that, for a pair of axes, one of which is an axis of symmetry of the section, $J = 0$. It is also zero for the principal axes of inertia. In all ordinary cases it can be computed by the aid of the simple transformation formula, exactly analogous to $I' = I_o + A\, h^2$,

$$J' = J_o + A\, k\, h,$$

in which $J'$ is the $J$ of the section referred to any rectangular co-ordinates, $O\,X$ and $O\,Y$, $k$ and $h$ are co-ordinates of the center of gravity, $G$, of the section; $J_o$ is the $J$ referred to axes parallel to $O\,X$ and $O\,Y$, with origin at $G$. Numerical illustrations of the computation of $J$ will be found in Sections 5 and 6. $J$ will be positive or negative according as the preponderance of the section is in the first and third, or second and fourth quadrants.

$I_x$, $I_y$, and $J$ are all quantities of the fourth degree, and are expressed in biquadratic inches or biquadratic centimeters, etc.

Noting that $x_k$ and $y_k$ are $q$ cos. $\lambda$ and $q$ sin. $\lambda$, respectively, Equations 8 and 9 become, accordingly,

$$f = \frac{N}{A} + \frac{N q (y - x \text{ tan. } \alpha) \text{ cos. } \lambda}{J - I_y \text{ tan. } \alpha} \quad \ldots\ldots\ldots\ldots\ldots (8')$$

and

$$f = \frac{N}{A} + \frac{N q (y - x \text{ tan. } \alpha) \text{ sin. } \lambda}{I_x - J \text{ tan. } \alpha} \quad \ldots\ldots\ldots\ldots\ldots (9')$$

Indeterminations in all these equations can be evaluated by the aid of trigonometric transformations such as were used in stating the second member of Equation 7, or by selecting between Equations 8 and 9, or between Equations 8′ and 9′.

The value of $f$ is now stated in the way most convenient for the common practical problem, which is to find the maximum value of $f$, that is, the value of $f$ for the $m$ most remote from $n$ $n$. This particular $m$ will be the $m$ most remote from $G$ $U$ on the same side of $G$ $U$ as $K$, as will be shown in Section 9. The routine in the solution of this problem will consist of:

(*a*) The solution of Equation 7;

(*b*) The identification of the most remote $m$, by sketching or drawing $G$ $U$—a line through $G$ the slope of which is tan. $\alpha$.

(c) The substitution of the tan. $\alpha$ and $x$, $y$ for this $m$ in Equations 8 or 9.

Parts I and II of the requirements of the problem are now accomplished. A numerical example will be worked out by way of illustration, and then attention will be directed to a study of the equations just obtained, with a view to meeting requirements III and IV of the problem (Section 2).

It will be worth while, in passing, to combine Equation 7 with Equations 8 or 9, and with Equations 8′ or 9′, and record expressions for $f$ in terms of known quantities, exclusively. They are found to be:

$$f = \frac{N}{A} + \frac{N (y_k I_y - x_k J) y + N (x_k I_x - y_k J) x}{I_x I_y - J^2} \quad \ldots\ldots (10)$$

or

$$f = \frac{N}{A} + N_q \frac{(I_y \text{ sin. } \lambda - J \text{ cos. } \lambda) y + (I_x \text{ cos. } \lambda - J \text{ sin. } \lambda) x}{I_x I_y - J^2} \quad . (10')$$

*Numerical Example.*—Problem.—A single 4 by 3 by $\frac{3}{8}$-in. angle, as a member of a framework, is attached at each end to a $\frac{1}{2}$-in. gusset

by a line of rivets of 2¼-in. gauge, through the 4-in. leg only. Suppose the direct stress is a thrust, $P$, acting in the line of the rivets and at mid-thickness* of the gusset. What is the maximum compressive unit stress in the angle?

Solution.—The solution consists of mere substitution in Equations 7 and 8 or 9, the determination of $J$ offering the only unusual difficulty.

Showing the data in a sketch (Fig. 2) in which the section is referred to the most convenient axes, the section is divided into two

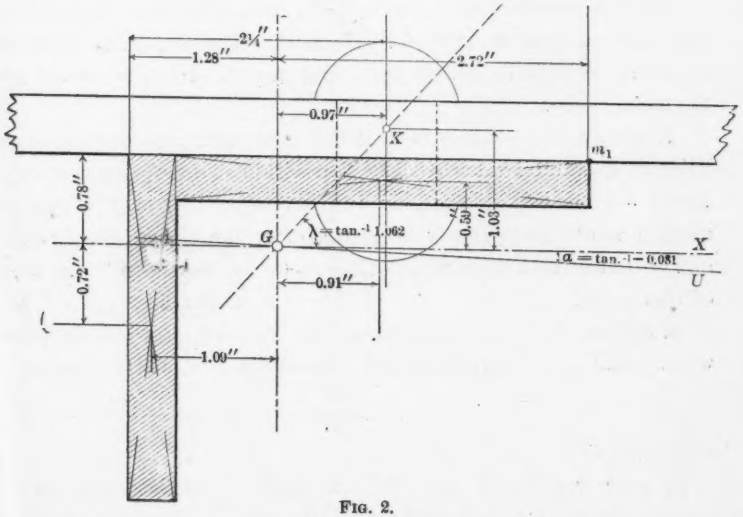



FIG. 2.

rectangles, whose centers of gravity are at (— 1.09, —0.72) and (0.91, 0.59), and whose areas are $3 \times \frac{3}{8} = 1.125$ and $3\frac{5}{8} \times \frac{3}{8} = 1.359$, respectively. Then, by $J' = J_o + A\ k\ h$, of the foot-note, p. 72, noting that $J_o$ of both rectangles is zero,

$$J = 1.125 \times - 1.09 \times - 0.72 + 1.359 \times 0.91 \times 0.59 = 1.61 \text{ in.}^4$$

The Carnegie book gives $I_x = 1.92$ in.$^4$, $I_y = 3.96$ in.$^4$, $A = 2.48$ in.

Then, by Equation 7, noting that $\tan. \lambda = \frac{1.03}{0.97} = 1.062$,

$$\tan. \alpha = \frac{1.92 - \overline{1.61 \times 1.062}}{1.61 - \overline{3.96 \times 1.062}} = \frac{0.21}{- 2.60} = - 0.081.$$

* This problem is solved upon other assumptions as to the point of application of the thrust, at the close of Section 9.

$G\,U$, accordingly, is in the second and fourth quadrants, and the extreme fibers of the angle will be the most remote corners in the first and third quadrants, with $m_1$ as the fiber subject to maximum compressive stress. The co-ordinates of $m_1$ are (2.72, 0.78), and observing that $y_k = 1.03$, substitution in Equation 9 yields

$$f = \frac{N}{2.48} + N\,\frac{1.03\left(0.78 - \overline{2.72 \times -0.081}\right)}{1.92 - \overline{1.61 \times -0.081}}$$

$$= 0.40\,N + 0.50\,N = 0.90\,N, \text{ the required answer.}$$

That is, the effect of the eccentricity is to make the extreme stress more than double the average. If the direct stress, $N$, is 10 000 lb., $f_{max.}$ will be 9 000 lb. per sq. in. Equation 8, of course, would give the same result.

If the strut is so long as to deflect materially, the section at the point of maximum sidewise deflection will have a longer $q$ and a different $\lambda$ from that in the preceding solution. For such a case the method would be precisely as above, after the change in direction and length of $G\,K$ had been estimated—a process outside the scope of this paper.

*6. Special Forms of Expressions for "f."*—In pure normal stress, when $q$ and $x_k$ and $y_k$, all vanish, Equations 8, 9, and 10 reduce to

$$f = \frac{N}{A} \qquad \text{.....(10a)}$$

as they should.

In pure flexure, $N = 0$, $q = \infty$, and $Nq$ is the value of the bending couple commonly written $M$. In this case Equations 8, 9 and 10, take the forms

$$f = \frac{M(y - x \tan.\ \alpha)\ \cos.\ \lambda}{J - I_y \tan\ \alpha.} \qquad \text{.....(8a)}$$

$$f = \frac{M(y - x \tan.\ \alpha)\ \sin.\ \lambda}{I_x - J \tan.\ \alpha} \qquad \text{.....(9a)}$$

$$f = M\,\frac{(I_y \sin.\ \lambda - J \cos.\ \lambda)\,y + (I_x \cos.\ \lambda - J \sin.\ \lambda)\,x}{I_x I_y - J^2} \qquad \text{.....(10b)}$$

Then, if $\lambda = 90°$, and $\alpha = 0°$, as it will if $J$ is zero, these equations all reduce to the familiar but highly special

$$f = \frac{My}{I_x} \qquad \text{.....(10c)}$$

The very common applicability of this equation arises from the fact that the rectangular beams and beams with I, C, or T-sections are naturally referred to rectangular axes for which $J$ is zero, and are loaded in a plane containing one of these axes.

*Numerical Examples.—1.*—A 5 by $3\frac{1}{4}$ by $\frac{1}{2}$-in. Z-bar acts as a purlin on a roof having a slope of 30°, its top flange projecting toward the ridge. It supports vertical loads which cause a maximum flexure of $M$ inch-pounds. Required, the extreme fiber stresses.

Solution.—Showing data, and taking axes as in Fig. 3, $I_x$ and

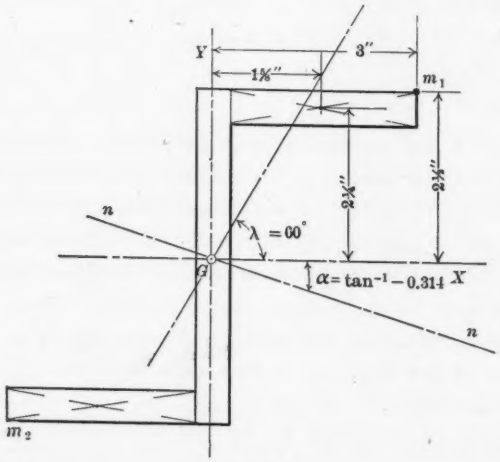



FIG. 3.

$I_y$ are given by steel handbooks as 19.19 in.⁴ and 9.05 in.⁴, and $J$, computed in a manner similar to that of the angle iron of the preceding section, is found to be $2(2.75 \times 0.5 \times 2.25 \times 1.625) = +10.05$ in.⁴

By Equation 7, tan. $\lambda$ being tan. 60° = 1.732,

$$\text{tan. } \alpha = \frac{19.19 - \overline{10.05 \times 1.732}}{10.05 - \overline{9.05 \times 1.732}} = -0.317$$

The extreme fibers are located accordingly at $m_1$ and $m_2$ the co-ordinates of which are $\pm 3.0$ and $\pm 2.5$. Using the values for $m_1$, and substituting in Equation 9a.

$$f = \frac{(2.5 - \overline{3.0 \times -0.317}) \times 0.866}{19.19 - \overline{10.05 \times -0.317}} M = 0.134\ M \text{ lb. per sq. in.}$$

The $f$ for $m_2$ would differ from this only in sign, and $\pm 0.134\ M$ is the required answer.

*2.*—Suppose the Z-bar of the preceding case replaced by a 6 by 12-in. rectangle with the 12-in. side normal to the roof slope. Find the fiber stresses.

Solution.—Taking $G\ X$ parallel to the short side, $J$ is zero, and $I_x$ and $I_y$ are 864 and 216 in.$^4$, respectively. Hence, by Equation 7,

$$\text{tan. } \alpha = \frac{864}{-216 \times 1.732} = -2.31$$

The extreme fibers are $\pm 3.0$ and $\pm 6.0$. Inserting in Equation 9a

$$f = \pm \frac{(6 - 3 \times -2.31) \times 0.866}{864} M = \pm 0.013\ M \text{ lb. per sq. in.,}$$

the required answer.

*7. The S-polygon of a Section.*—As has been observed, any case of flexure may be treated as a combination of direct normal stress and pure flexure, either of which may, of course, be zero. The treatment of the pure flexure is the only part offering much difficulty. The difficulty with pure flexure is specially great when the extreme value of $f$ is to be determined, and the proper values of $x$ and $y$, substituted in Equation 10b, have to be computed in advance. The diminution of the difficulty in this most important practical problem is the next field of inquiry.

Inspection of Equations 8a, 9a and 10b reveals that the $f$ for any $m$ may be obtained by dividing $M$ by a quantity in which, for a given $\lambda$, the only variables are the co-ordinates of $m$. This quantity, in its most general form, is, from Equation 10b

$$S = \frac{I_x I_y - J^2}{(y I_y - x J) \text{ sin. } \lambda + (x I_x - y J) \text{ cos. } \lambda} \quad \ldots\ldots\ldots (11)$$

a quantity which might be called the flexure modulus of the section for the point, $x$, $y$, or, more briefly, the section modulus for $x$, $y$. Special values of it for extreme positions of $m$ and for special values of $\lambda$ are what are given in the steel manufacturers' handbooks in the case of I-beams, channels and tees as the section moduli of the shapes concerned. In this paper it will be referred to simply as $S$, occasionally with a special suffix.

$S$ is a quotient obtained by dividing a quantity of the eighth degree by one of the fifth. It is, therefore, of the third degree. It may

be looked upon as the statical moment of an area.* Thus, only can $M$ divided by $S$ yield a stress-intensity. In the special case in which $\lambda = 90°$, and $J$ is zero, $S$ takes the familiar form

$$S_a = \frac{I_x}{y} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Returning to the examination of Equation 11, it at once appears that, for a fixed $m$ and varying $\lambda$, that equation is the polar equation of a straight line, that is, a line the radius vector of which, at any inclination, $\lambda$, would be proportional to the $S$ for that $\lambda$. That is, the $S$-line, if it may be so called, is the simplest possible graphical exhibit for the values of $S$ for any one $m$ for all values of $\lambda$. This at once suggests the determination of the $S$-lines for all points of the section which might be extreme fibers of the section. As will be seen in what follows, these $S$-lines will define a surface which may be called the $S$-polygon of the section. With the $S$-polygon given, merely drawing a line through $G$ with the inclination, $\lambda$, defines two radii vectores, $S'$ and $S''$, measured from $G$ toward and away from $K$, respectively. $S'$ and $S''$ being measured to the proper scale, the most important values of $f$ in the most difficult case can be had by mere substitution in

$$f' = \frac{N}{A} + \frac{Nq}{S'} = \frac{N}{A} + \frac{M}{S''} \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

$$f'' = \frac{N}{A} + \frac{Nq}{S''} = \frac{N}{A} - \frac{M}{S''} \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

which are perfectly general expressions for the extreme values of $f$, Of course, in pure flexure, $N$ vanishes, and they become

$$f' = \frac{M}{S'} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13')$$

$$f'' = \frac{M}{S''} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14')$$

*8.—Construction of the S-polygon.*—Referring Equation 13 to rectangular co-ordinates by substituting $x$ and $y$ for $S \cos. \lambda$, and $S \sin. \lambda$, respectively, we have

$$y = \frac{x_m I_x - y_m J}{x_m J - y_m I_y} x - \frac{I_x I_y - J^2}{x_m J - y_m I_y} \quad \ldots\ldots\ldots\ldots (15)$$

a line which is parallel to the neutral axis (Equation 17 in Section 9) for a $K$ at $x$, $y$, on the same side of $G$ with $K$ (that is, on the opposite side of $G$ from $n\ n$), and, if the same units be selected to rep-

* The units in which it is expressed may be called inch square-inches, following the analogy with inch-pounds. Inch square-inches will be abbreviated to inches$^2$ or in.$^2$

resent third-degree units as to represent simple length, $A$ times as far from $G$ as $n\ n$ is.

Of course, the values of $x$ and $y$, for all points on the perimeter of the given section could be substituted for ($x_m$ and $y_m$) in Equation 15, the corresponding lines plotted, and the space within all these lines taken as the $S$-polygon. This might have to be resorted to for parts of the section bounded by curved lines, but it can be done more easily in the case of the familiar rolled steel shapes. In these cases the extreme $m$'s will all lie upon a small number of straight lines which bound, but do not, even if produced, cross the section. These lines will constitute what may be called the circumscribing polygon. The $S$-polygon will have a side corresponding to each apex of the circumscribing polygon. These sides will be $S$-lines, intersecting and forming apices of the $S$-polygon whenever $\lambda$ has such a value as will cause two adjacent apices of the circumscribing polygon to be extreme fibers at the same time. This will happen, of course, whenever the neutral axis is parallel to the side of the circumscribing polygon.

Locating and connecting the apices will usually be the most convenient way of constructing the $S$-polygon. The co-ordinates of an apex of the $S$-polygon can be determined by substituting the co-ordinates ($x_a$, $y_a$) and ($x_b$, $y_b$) of two successive apices, $A$ and $B$, of the circumscribing polygon in Equation 15, and solving the two resulting equations for the co-ordinates of the intersection of the resulting $S$-lines. Performing this operation will yield for the co-ordinates ($x_{ab}$, $y_{ab}$) of the apex of the $S$-polgyon corresponding to the side $A\ B$,

$$\left.\begin{aligned} x_{ab} &= \frac{(x_a - x_b)\,J - (y_a - y_b)\,I_y}{x_a\,y_b - x_b\,y_a} \\ y_{ab} &= \frac{(x_a - x_b)\,I_x - (y_a - y_b)\,J}{x_a\,y_b - x_b\,y_a} \end{aligned}\right\} \quad \ldots\ldots\ldots (16)$$

If, as very commonly happens, the side of the circumscribing polygon is parallel to an axis of reference, these expressions become materially simplified. If, for instance, it is parallel to the $X$-axis, $y_a = y_b$, and Equation 16 becomes

$$\left.\begin{aligned} x_{ab} &= \frac{J}{y_a} \\ y_{ab} &= \frac{I_x}{y_a} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (16')$$

If the line is parallel to the $Y$-axis, $x_a = x_b$, and Equation 16 becomes

$$\left.\begin{aligned} x_{ab} &= \frac{I_y}{x_a} \\ y_{ab} &= \frac{J}{x_a} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16'')$$

The actual $S$-polygon, as a fixed geometrical property of a section, and one which can be constructed with great ease any time (see numerical examples below) for the simpler sections, and can be constructed once for all and kept on file for the more difficult sections, is presented as a satisfaction of the requirements of III and IV of Section 2.

The actual methods of computation and use of the $S$-polygon will be illustrated in the following numerical examples.

*Numerical Examples.*—Required the $S$-polygon for each of the four following sections, viz.:

(*a*) 6 by 12-in. rectangle;

(*b*) 8-in. 18-lb. I-beam;

(*c*) 10-in. 20-lb. channel;

(*d*) 5 by ½-in. Z-bar.

Solution.—The natural axes of reference for all these shapes are the gravity axes parallel to the principal dimensions, and shown in Figs. 4, 5, 6, and 7. In each of the first three sections at least one of the axes is an axis of symmetry and $J$ will be zero, and, consequently, the simple Equations 16′ and 16″ will suffice. For the Z-bar, however, Equation 16, in its general form, will be needed. The sides and apices of the $S$-polygons will be designated with the lower-case letters of the corresponding apices and sides of the circumscribing polygon.

The four shapes will now be taken up in order.

(*a*)—The given 6 by 12-in. rectangle is shown as $A\ B\ C\ D$ in Fig. 4.

$$I_x = \frac{b\,d^3}{12} = \frac{6 \times 12 \times 12 \times 12}{12} = 864 \text{ in.}^4;$$

$$I_y = \frac{b^3\,d}{12} = \frac{6 \times 6 \times 6 \times 12}{12} = 216 \text{ in.}^4;$$

$$J = 0.$$

It will suffice to compute the co-ordinates of the apices, $a\ b$ and $b\ c$; symmetry will locate the other two, $c\ d$ and $a\ d$.

The co-ordinates of $A, B$, and $C$ are $(-3, 6)$, $(3, 6)$ and $(3, -6)$. These are the $(x_a, y_a)$, $(x_b, y_b)$, etc., of Equations 16, 16′, and 16″.

By Equation 16′, $x_{ab} = \dfrac{J}{y_a} = \dfrac{0}{6} = 0$; $y_{ab} = \dfrac{I_x}{y_a} = \dfrac{864}{6} = 144$ in.$^3$

By Equation 16″, $x_{bc} = \dfrac{I_y}{x_b} = \dfrac{216}{3} = 72$ in.$^3$; $y_{bc} = \dfrac{J}{x_b} = \dfrac{0}{3} = 0$.

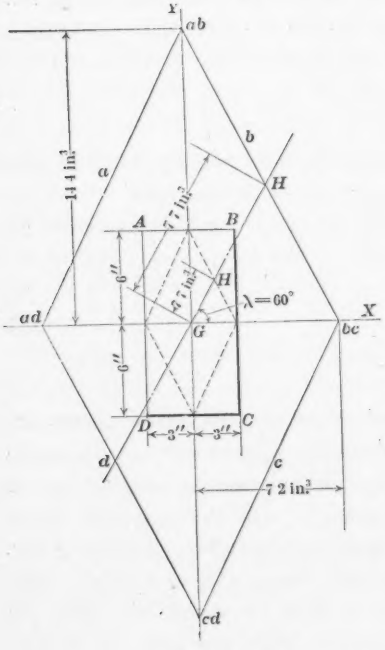



FIG. 4.

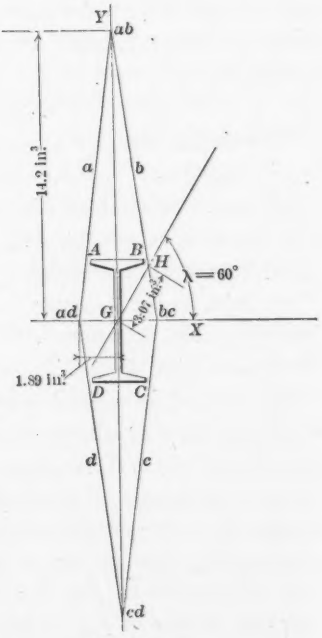



FIG. 5.

The four apices are, accordingly, $(0, \pm 144)$ and $(\pm 72, 0)$, and are plotted in Fig. 4 to an arbitrarily selected scale.

Remarks.—The sides of this $S$-polygon are parallel to the diagonals of the rectangle, and an $S$-polygon, therefore, could be constructed by merely connecting the middle points of adjacent sides of the rectangle. Such a polygon is shown dotted in Fig. 4. The scale of this $S$-polygon is readily determined by computing the numerical value, $\dfrac{b\ d^2}{6}$, of its vertical semi-diagonal.

The apices are seen to be on the axes at distances from $G$ which represent the familiar section moduli in the planes of the axes along which they are laid off. Consequently, in dealing with rectangles in general, or similar simple sections, no formal use of Equations 16′ and 16″ is necessary. The section moduli once known, they are laid off to convenient scale along the proper axes, and the apices thus determined are connected. This would apply to any section referred to rectangular gravity axes for which $J$ is zero. This method will be exemplified in the next two cases.

($b$)—For the 8 in., 18-lb. I-beam, the steel handbooks give the section modulus for the axis, $G\ X$, as 14.2 in.$^3$ The other is found by dividing the $I_y$ by half the flange width—both given by the handbooks, that is, $\frac{3.78}{2.0} = 1.89$ in.$^3$ Laying off the 14.2 upward and downward from $G$, and the 1.89 to the right and left of $G$, the $S$-polygon of Fig. 5 is established.

($c$)—For the 10-in., 20-lb. channel, the two section moduli, 15.7 and 1.34 in.$^3$, given by the handbooks must be supplemented by a third one, since $G\ Y$ is not an axis of symmetry. This third one is $I_y$ divided by the distance from $G$ to the back of the channel. Using the handbook data, this is found to be $\frac{2.85}{0.61} = 4.67$ in.$^3$ Laying off 15.7 upward and downward from $G$, 1.34 from $G$ along $G\ X$ and in the same direction as the projecting flanges, and 4.67 along $G\ X$ in the opposite direction, the $S$-polygon of Fig. 6 is located.

($d$)—For the 5 by $\frac{1}{2}$-in. Z-bar, the handbooks furnish $I_x = 19.19$ in.$^4$, $I_y = 9.05$ in.$^4$, and, in Section 7, $J$ was found to be 10.05 in.$^4$ $J$ will be positive for the section as drawn in Fig. 7. The three apices, $a\ b$, $b\ c$, and $c\ d$, will be located by computation, and the other three, $d\ e$, $e\ f$, $fa$, will follow by symmetry. The coordinates of $A$, $B$, $C$, and $D$ are (— 0.25, 2.50), (3.0, 2.50), (3.0, 2.0), and (0.25, — 2.50)

By Equation 16′,

$$x_{ab} = \frac{10.05}{2.50} = 4.02 \text{ in.}^3; \quad y_{ab} = \frac{19.19}{2.50} = 7.68 \text{ in.}^3.$$

By Equation 16″,

$$x_{bc} = \frac{9.05}{3.0} = 3.02 \text{ in.}^3; \quad y_{bc} = \frac{10.05}{3.0} = 3.35 \text{ in.}^3.$$

By Equation 16,

$$x_{cd} = \frac{(3.0 - 0.25)10.05 - (2.0 - 2.5)9.05}{3.0 \times -2.5 - 0.25 \times 2.0} = 1.63 \text{ in.}^3;$$

$$y_{cd} = \frac{(3.0 - 0.25)19.19 - (2.0 - 2.5)10.05}{3.0 \times -2.5 - 0.25 \times 2.0} = -0.94 \text{ in.}^3.$$

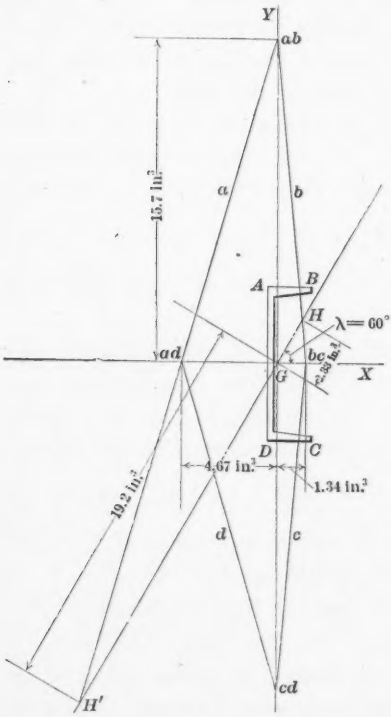



FIG. 6.

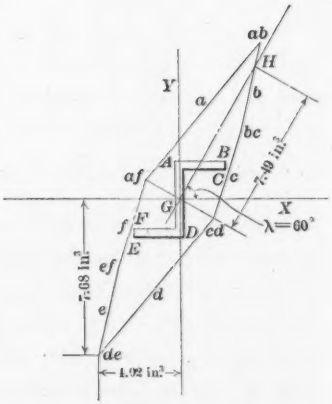



FIG. 7.

These and the same with signs reversed establish the desired *S*-polygon plotted in Fig. 7. Similarly, any section can be treated.

*9. Examples of the Use of the S-Polygon.*—The following numerical examples will illustrate some of the uses of the *S*-polygon.

Problem 1.—Find the extreme fiber-stress in each of the four sections of Figs. 4 to 7, assuming each to be acting as a purlin upon a roof inclined 30° to the horizon and set with its *G X*-axis parallel to the roof slope. Assume a flexure of *M*, in pounds, in a vertical

plane, and assume that each purlin is set so as to make $B$ the highest corner.

Solution.—Draw a line with a slope, $\lambda = (90° - 30°) = 60°$ (representing the trace of the plane of loads) through $G$ in each $S$-polygon of Figs. 4 to 7, and scale off the distance, $G\,H$, along this line to the $S$-polygon perimeter, taking the shorter of the two lengths when there is a difference. The results for the four sections are as dimensioned 77, 3.07, 2.33, and 7.49 in.$^3$, respectively. The results, accordingly, are by Equation 13, $N$ being zero:

For the rectangle:

$$f_{max.} = \pm \frac{M}{77} = \pm 0.013\ M \text{ lb. per sq. in.}$$

For the 8-in., 18-lb. I-beam:

$$f_{max.} = \pm \frac{M}{3.07} = \pm 0.325\ M \text{ " " " "}$$

For the 10.-in., 20-lb. channel:

$$f_{max.} = + \frac{M}{2.33} = + 0.428\ M \text{ " " " "}$$

For the 5 by $\frac{1}{2}$-in. Z-bar:

$$f_{max.} = \pm \frac{M}{7.49} = \pm 0.134\ M \text{ " " " "}$$

Here are verified the results of the numerical example of Section 6. Incidentally, note the great economy (for such a load) of the Z-bar over the heavier channel and I-beam.

Problem 2.—In each of the sections in the preceding problem, which are the fibers subject to the stresses given?

Solution.—In the rectangle and I-beam, $H$ might be taken on either the $b$-line or the $d$-line. Hence, $B$ and $D$ are both extreme fibers in these cases. In the channel, similarly, $B$ is indicated, and in the Z-bar, $B$ and $E$.

Problem 3.—In the channel of Problem 1, what is the magnitude and nature of the stress at the point, $A$, under the given load?

Solution.—Extending $G\,H$ to the intersection, $H'$, with the $a$-line produced, $G\,H'$ is scaled off as 19.2 in.$^3$ Hence, $f_A = \frac{M}{19.2} = 0.052\ M$. To determine whether it is tension or compression, observe that $N$, though zero in amount, may be treated as a compressive force at infinity on $G\,H$ above $G$, or as a tensile force at infinity below $G$.

Assume the former, then $H'$ is on the opposite side of $G$ from $K$, and $f_A$, accordingly (Section 7), is of opposite sign to $N$, and, therefore, is tensile. The same result follows, of course, from the opposite assumption.

Problem 4.—In the Z-bar of Fig. 7, what is the most favorable plane of loading, and what will then be the position of the neutral axis?

Solution.—The most favorable plane of loading is obviously that yielding the maximum $S$. This, by inspection of the figure, would be a plane the trace of which would pass through $a\ b$ and $d\ e$, and have for a slope $\tan.^{-1}\frac{7.68}{4.02}$. This trace, passing through $a\ b$ and $d\ e$, indicates that $A$ and $B$, as well as $D$ and $E$, are then all extreme fibers. Hence, the neutral axis is then parallel to the flanges, $A\ B$ and $D\ E$.

Similarly, the least favorable plane of loads might be located; obviously, it will be perpendicular to the $a$-line and $d$-line.

Problem 5.—Through what extremes would $f_{max.}$ pass, if the Z-bar of Problem 1 were to make a complete revolution about its longitudinal axis, the load remaining vertical?

Solution.—Scaling off the extreme values of $S$ indicated in the preceding problem, they are found to be 8.68 and 1.85 in.$^3$ The extremes of $f_{max.}$ are $\frac{M}{8.68} = 0.116\ M$, and $\frac{M}{1.85} = 0.540\ M$.

Problem 6.—What is the least favorable plane of loads for the rectangle of Fig. 4?

Solution.—Minimum $S$ will occur for planes normal to either diagonal of the rectangle.

Problem 7.—What plane of loads will make the neutral axis vertical in the Z-bar of Fig. 7:

Solution.—If the neutral axis is vertical, $B\ C$ and $E\ F$ will be the extreme fibers, and the plane of loads must pass through $b\ c$ and $e\ f$.

Problem 8.—A channel is to be selected to act as a purlin; trusses 10 ft. on centers; slope of roof 30° to horizontal; purlins 6 ft. apart in plan; loads, dead 10 lb. and snow 20 lb. per sq. ft. of plan, and wind 25 lb. per sq. ft. of roof surface; fiber stress not to

exceed 16 000 lb. per sq. in. for the worst combination, considering (*a*) that the maximum snow and wind may act simultaneously; (*b*) that they may not so act.

Solution.—The loads per linear foot upon the purlin for the three

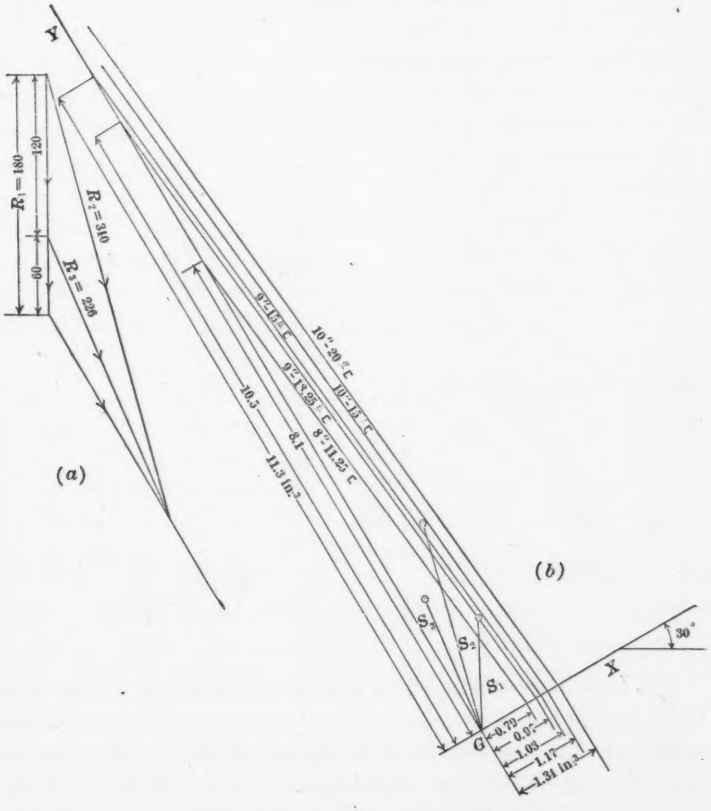



FIG. 8.

loads are, noting that the distance between purlin centers on the slope is 6.93 ft.,

$w_d = 6 \times 10 = 60$ lb. per lin. ft., vertical,
$w_s = 6 \times 20 = 120$ " " " " "
$w_w = 6.93 \times 25 = 173.2$ " " " " normal to roof slope.

Fig. 8*a* is a force-magnitude polygon showing the important result-

ants, $R_1$, $R_2$ and $R_3$ in magnitude and direction. They are the resultants of $w_d$ and $w_s$, of $w_d$, $w_s$, $w_w$, and of $w_d$ and $w_w$, respectively. They give rise to three different flexures, $M_1$, $M_2$ and $M_3$, in their respective planes, and call for three different values of $S$: $S_1$, $S_2$ and $S_3$, in those planes.

$$S_1 = \frac{M_1}{16\,000} = \frac{180 \times 10 \times 10 \times 12}{8 \times 16\,000} = 180 \times 0.0094 = 1.69 \text{ in}^3.$$

Similarly, $S_2$ and $S_3$ are 3.19 and 2.12 in.$^3$, respectively.

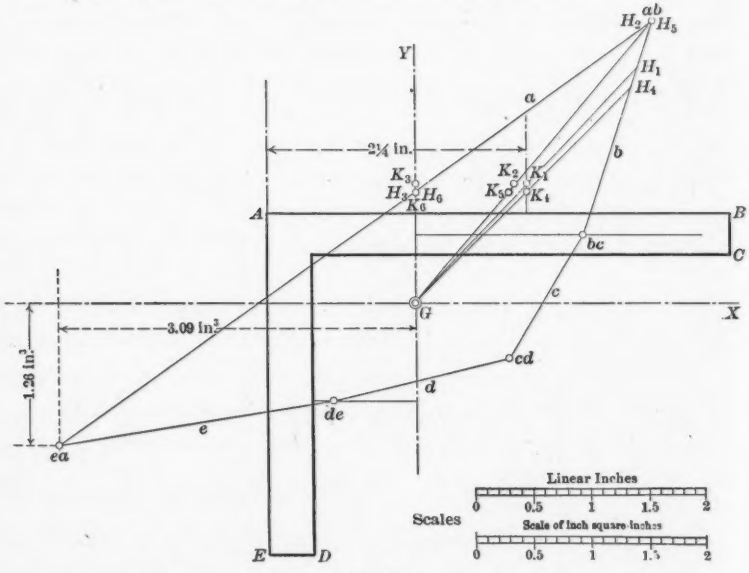



FIG. 9.

On inspection of Fig. 6 it is seen that a single side (that pertaining to $B$) of the $S$-polygon for each channel will suffice. Accordingly, this side is plotted for a promising list of channels, using only such data as the handbook furnishes. $S_1$, $S_2$ and $S_3$ are laid off from $G$ parallel to the resultants to which they respectively correspond. This work is shown in Fig 8$b$. Condition ($a$) calls for a channel which can furnish $S_1$ and $S_2$, and condition ($b$) requires $S_1$ and $S_3$. A glance at the sketch shows that for ($a$) a 10-in. 15-lb. channel is required, and for ($b$) a 9-in. 13.25-lb. channel. The latter is so close a fit that one of the next two larger sizes might well be preferred, in view of the sensitiveness of the section to a slight change in position.

Problem 9.—Suppose the 4 by 3 by $\frac{3}{8}$-in. angle of the example at the close of Section 5 to be exposed to a thrust, $P$ (= 18 000 lb.) applied successively at the six different $K$'s, shown in Fig. 9. The first three are at mid-thickness of a $\frac{1}{2}$-in. gusset, and the second three similarly on the center plane of a $\frac{3}{8}$-in. gusset. In each set, the $K$'s are, respectively, at gauge $2\frac{1}{4}$ in., at the most favorable gauge, and opposite $G$. Required the $f_{max.}$ for each case.

Solution.—Here are really six problems, each equal in complexity to that at the close of Section 5. In fact, the first one is that very problem, here to be solved again for comparison. The $S$-polygon simplifies matters so greatly that the six problems will be taken up together. It is merely a question of getting the $M$'s and $S''$s for substitution in Equation 13. $S'$ is, in each case, $G\ H$, as usual, and $M = P\ q$, where $q$ is $K\ G$. The six $q$'s and $S''$s are scaled from Fig. 9, where the section and its $S$-polygon are plotted, and the substitution is carried out in Table 1.

TABLE 1.

| Case. | $q$. | $S'$. | $\frac{M}{S'} = \frac{P\ q}{S'}$. | $\frac{P}{A}$ | $fmax = \frac{P}{A} + \frac{M}{S'}$ | Location of $f_{max.}$ |
|---|---|---|---|---|---|---|
| $K_1$ | 1.41 in. | 2.82 in.$^3$ | 9 000 | 7 200 | 16 200 | $B$ |
| $K_2$ | 1.35 " | 3.21 " | 7 600 | 7 200 | 14 800 | $A\ B$ |
| $K_3$ | 1.03 " | 0.97 " | 19 100 | 7 200 | 26 300 | $A$ |
| $K_4$ | 1.37 " | 2.66 " | 9 300 | 7 200 | 16 500 | $B$ |
| $K_5$ | 1.27 " | 3.21 " | 7 100 | 7 200 | 14 300 | $A\ B$ |
| $K_6$ | 0 97 " | 0.97 " | 18 000 | 7 200 | 25 230 | $A$ |

The location of the fiber, subject to $f_{max.}$ in each case, is indicated by the letter of the $S$-line on which $H$ falls, and is recorded in the table as a matter of interest.

The fluctuation of $f$ is seen to be considerable with these changes in the position of $K$. In an actual frame these variations would doubtless be less serious, but would be diminished only at the expense of secondary stresses in the neighboring members. These stresses would be of a flexural or torsional character very difficult to estimate.

*Section 10.—Concerning S-Polygons of Specially Important Sections.*—Table 2 gives the co-ordinates of the apices of the $S$-polygons for the standard American Z-bars, and Plate V shows these same $S$-polygons plotted to scale. It is believed that the reader will be able from the foregoing to establish the $S$-polygons

for the standard channels so easily as to make it inadvisable to take up the space to show them here. For I-beams no computation is needed beyond what is given in the steel handbooks. Thus would be covered the most important purlin shapes. The writer has never established the *S*-polygons for angles, but rests content in that they are relatively of minor importance.

TABLE 2.—APEX CO-ORDINATES FOR THE *S*-POLYGONS OF THE AMERICAN STANDARD Z-BARS, EXPRESSED IN INCHES.[3]

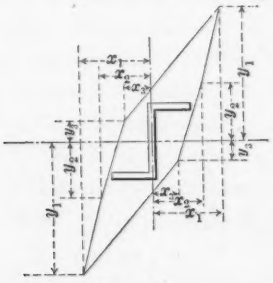
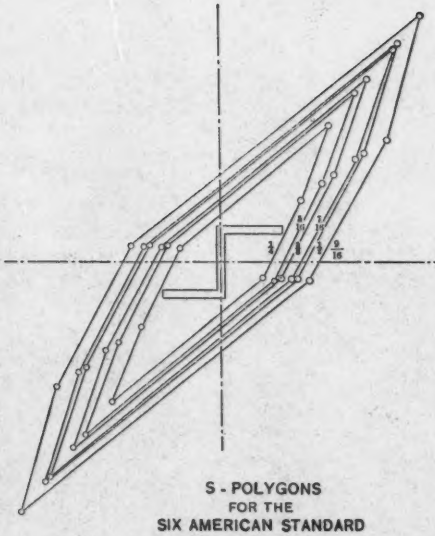



FIG. 10.

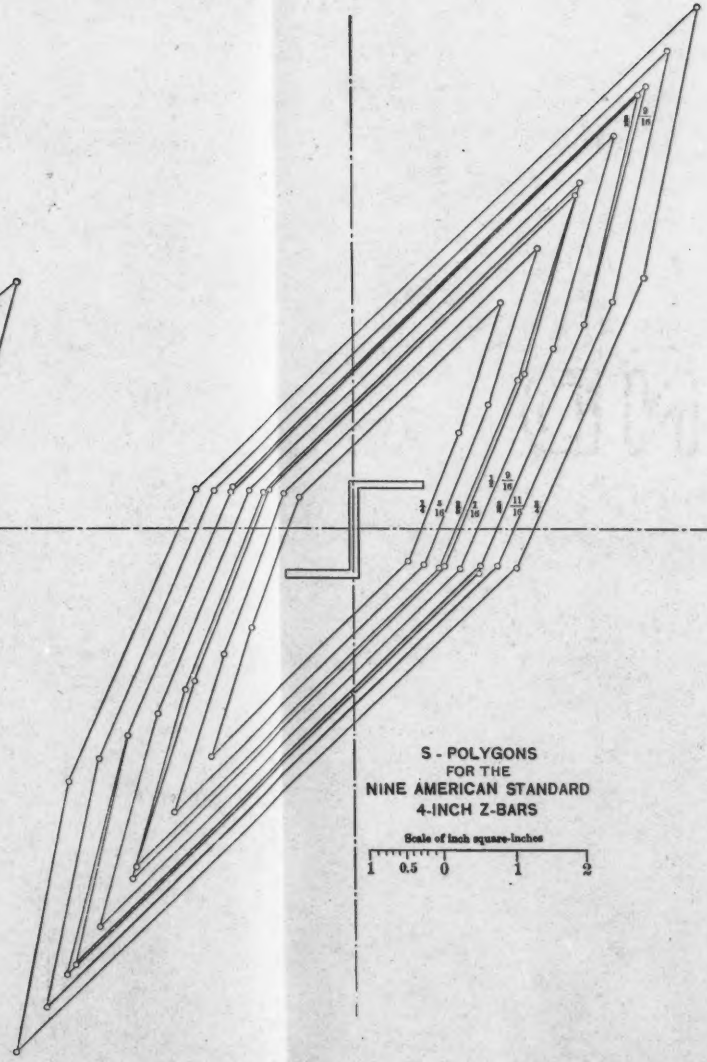
| Section. | $x_1$ | $y_1$ | $x_2$ | $y_2$ | $x_3$ | $y_3$ |
|---|---|---|---|---|---|---|
| 3 × 2 1/2 × 1/4 | 1.50 | 1.92 | 1.10 | 0.88 | 0.56 | 0.20 |
| 3 1/16 × 2 3/8 × 15/64 | 1.88 | 2.38 | 1.40 | 1.11 | 0.72 | 0.23 |
| 3 × 2 1/16 × 3/8 | 2.04 | 2.57 | 1.57 | 1.22 | 0.81 | 0.22 |
| 3 1/16 × 2 3/8 × 7/16 | 2.38 | 2.98 | 1.88 | 1.44 | 0.98 | 0.24 |
| 3 × 2 1/16 × 1/2 | 2.45 | 3.06 | 1.99 | 1.51 | 1.05 | 0.22 |
| 3 1/16 × 2 1/4 × 9/16 | 2.76 | 3.43 | 2.30 | 1.71 | 1.22 | 0.23 |
| 4 × 3 1/16 × 1/4 | 2.02 | 3.14 | 1.44 | 1.37 | 0.74 | 0.42 |
| 4 1/16 × 3 1/4 × 5/16 | 2.54 | 3.91 | 1.84 | 1.74 | 0.95 | 0.48 |
| 4 1/8 × 3 3/16 × 7/16 | 3.06 | 4.67 | 2.26 | 2.10 | 1.18 | 0.53 |
| 4 × 3 1/16 × 7/16 | 3.13 | 4.83 | 2.37 | 2.20 | 1.25 | 0.50 |
| 4 1/16 × 3 1/2 × 1/2 | 3.60 | 5.50 | 2.77 | 2.54 | 1.47 | 0.53 |
| 4 1/8 × 3 3/16 × 9/16 | 4.06 | 6.18 | 3.19 | 2.88 | 1.71 | 0.56 |
| 4 × 3 1/16 × 1/2 | 3.94 | 6.05 | 3.18 | 2.86 | 1.73 | 0.50 |
| 4 1/16 × 3 1/2 × 11/16 | 4.35 | 6.65 | 3.58 | 3.18 | 1.97 | 0.51 |
| 4 1/8 × 3 7/16 × 3/4 | 4.77 | 7.26 | 4.00 | 3.50 | 2.22 | 0.52 |
| 5 × 3 1/2 × 5/16 | 4.80 | 5.34 | 2.00 | 2.26 | 1.04 | 0.80 |
| 5 1/16 × 3 5/16 × 3/8 | 3.38 | 6.39 | 2.45 | 2.74 | 1.29 | 0.90 |
| 5 1/8 × 3 3/8 × 7/16 | 3.97 | 7.44 | 2.92 | 3.22 | 1.55 | 0.98 |
| 5 × 3 1/2 × 1/2 | 4.02 | 7.68 | 3.02 | 3.35 | 1.63 | 0.94 |
| 5 1/16 × 3 5/16 × 9/16 | 4.55 | 8.62 | 3.47 | 3.80 | 1.90 | 0.99 |
| 5 1/8 × 3 3/8 × 5/8 | 5.09 | 9.57 | 3.94 | 4.26 | 2.17 | 1.03 |
| 5 × 3 1/2 × 11/16 | 4.94 | 9.47 | 3.91 | 4.25 | 2.20 | 0.94 |
| 5 1/16 × 3 5/16 × 3/4 | 5.42 | 10.34 | 4.37 | 4.67 | 2.48 | 0.97 |
| 5 1/8 × 3 3/8 × 13/16 | 5.91 | 11.20 | 4.84 | 5.10 | 2.78 | 0.99 |
| 6 × 3 1/2 × 3/8 | 3.85 | 8.44 | 2.75 | 3.48 | 1.46 | 1.36 |
| 6 1/16 × 3 5/16 × 7/16 | 4.52 | 9.83 | 3.27 | 4.10 | 1.75 | 1.50 |
| 6 1/8 × 3 3/8 × 1/2 | 5.20 | 11.22 | 3.81 | 4.72 | 2.06 | 1.62 |
| 6 × 3 1/2 × 9/16 | 5.24 | 11.55 | 3.91 | 4.88 | 2.15 | 1.57 |
| 6 1/16 × 3 5/16 × 11/16 | 5.87 | 11.82 | 4.44 | 5.47 | 2.47 | 1.65 |
| 6 1/8 × 3 3/8 × 13/16 | 6.50 | 14.10 | 4.98 | 6.07 | 2.80 | 1.71 |
| 6 × 3 1/2 × 3/4 | 6.32 | 14.04 | 4.94 | 6.06 | 2.83 | 1.60 |
| 6 1/16 × 3 5/16 × 15/16 | 6.89 | 15.22 | 5.47 | 6.62 | 3.17 | 1.64 |
| 9 1/8 × 3 3/8 × 7/16 | 7.48 | 16.40 | 6.02 | 7.18 | 3.52 | 1.67 |



S - POLYGONS
FOR THE
SIX AMERICAN STANDARD
3-INCH Z-BARS

Scale of inch square-inches

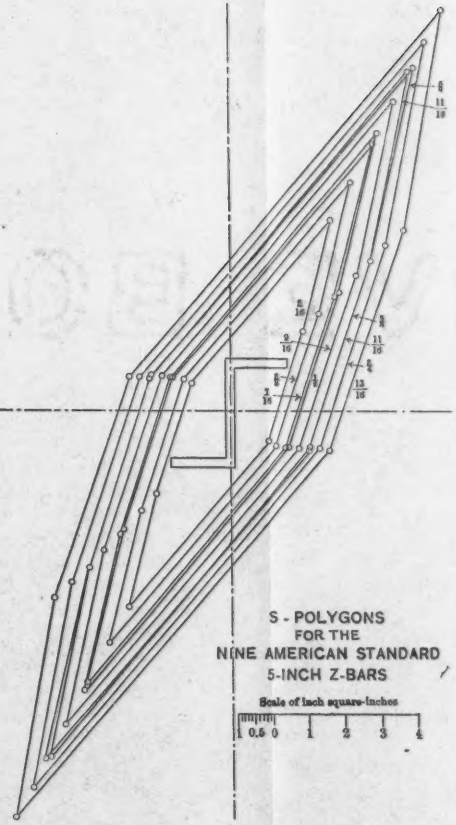
1 0.5 0 1 2



S - POLYGONS
FOR THE
NINE AMERICAN STANDARD
4-INCH Z-BARS

Scale of inch square-inches

1 0.5 0 1 2



S - POLYGONS
FOR THE
NINE AMERICAN STANDARD
5-INCH Z-BARS

Scale of inch square-inches

1 0.5 0 1 2 3 4



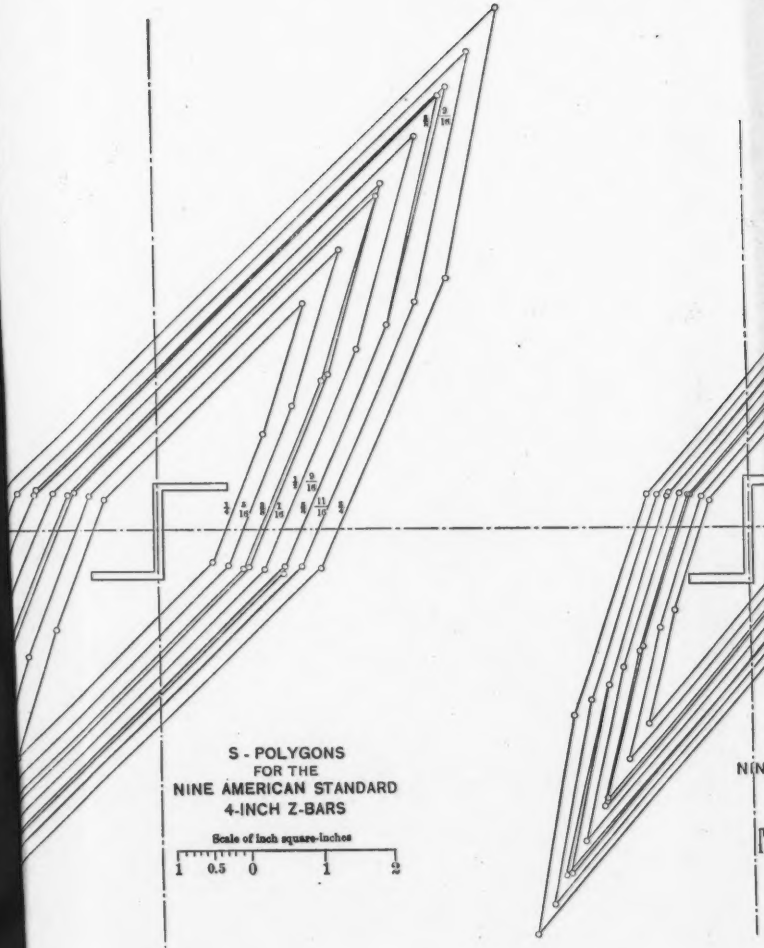
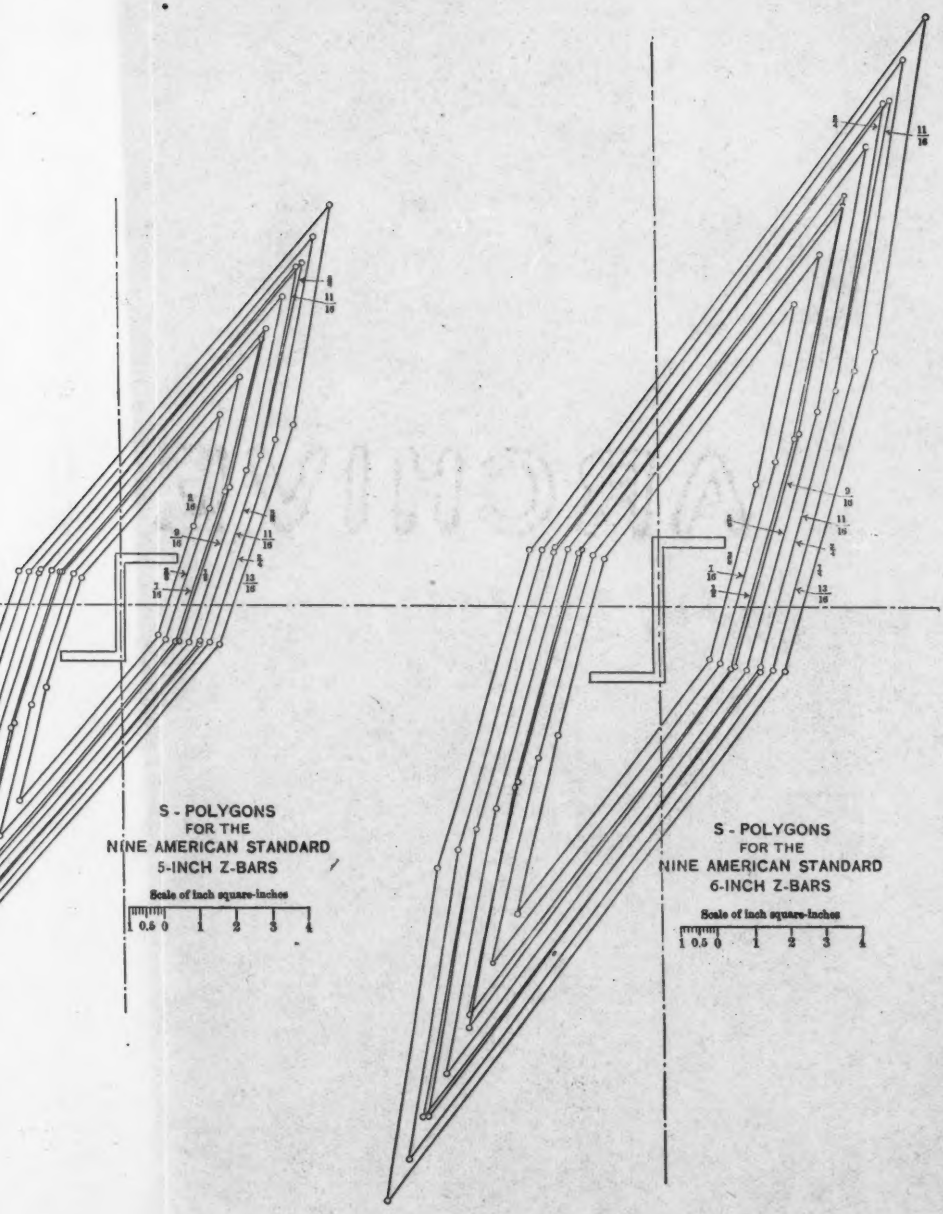

S - POLYGONS
FOR THE
NINE AMERICAN STANDARD
4-INCH Z-BARS
Scale of inch square-inches
1 0.5 0 1 2

PLATE V.
PAPERS, AM. SOC. C. E.
FEBRUARY, 1906.
JOHNSON ON
GENERAL FLEXURE.



S - POLYGONS
FOR THE
NINE AMERICAN STANDARD
5-INCH Z-BARS

Scale of inch square-inches

1 0.5 0 1 2 3 4

S - POLYGONS
FOR THE
NINE AMERICAN STANDARD
6-INCH Z-BARS

Scale of inch square-inches

1 0.5 0 1 2 3 4

## APPENDIX.

*11. The Equation and Properties of the Neutral Axis.*—Setting $f = 0$ in Equation 10, and rearranging, the equation of the neutral axis is found to be

$$y = \frac{x_k I_x - y_k J}{x_k J - y_k I_y} x + \frac{I_k I_y - J^2}{A(x_k J - y_k I_y)} \quad \ldots\ldots\ldots\ldots (17)$$

the coefficient of $x$ being its slope, and the constant term its intercept, $b$, on the axis of $Y$. These values might also have been obtained as tan. $\alpha$. from Equation 7, and $v_o$ sec. $\alpha$, from Equations 5 and 6.

Inspection of Equation 17 will reveal a number of important facts.

In the extreme case, when $K$ is at $G$, $y_k$ and $x_k$ vanish, tan. $\alpha$ becomes indeterminate, and $b$ becomes infinite. That is, if $N$ be applied at the center of gravity of a section, the neutral axis will be at an infinite distance, and with no determinate direction. The $f$ is then constant throughout the section, as might have been foreseen. This is the case of pure normal stress (compression or tension).

For the other extreme, where $K$ is at infinity (the condition for pure flexure), either or both of $x_k$ and $y_k$ become infinite, tan. $\alpha$ is determinate in any given problem (Equation 7) and $b$ vanishes. That is, in pure flexure the neutral axis passes through the center of gravity of the section at an inclination depending upon $\lambda$.

For intermediate positions of $K$, the neutral axis has a determinate slope, and is at a finite distance from $G$, dependent upon the location of $K$, and the greater the distance, $K\ G$, the nearer to $G$ will be the neutral axis, and *vice versa.*

It can be shown that the quantity, $I_x\ I_y - J^2$ is never negative With the aid of this fact, and by finding the intercept of a line through $K$ parallel to $n\ n$, it will be seen that $K$ and $n\ n$ always lie upon opposite sides of $G\ U$, as might have been foreseen.

Since tan. $\alpha$ depends solely upon the ratio of $y_k$ and $x_k$, and not at all upon their actual magnitudes, it is evident that, for all $K$'s on a line through $G$, the neutral axes will be parallel, and conversely.

Further, the intersection of neutral axes for any two $K$'s upon any straight line, $y = l\ x + b$ will be found to have for its coordinates

$$\left.\begin{aligned} x &= \frac{J - l I_y}{A\ b} \\ y &= \frac{I_x - l J}{A\ b} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (18)$$

quantities dependent only upon the constants of the given line and of the section. Hence it appears that for $K$'s moving on any straight

line the neutral axis rotates about a fixed point, given by Equation 18, and conversely. If the line passes through $G$, $b$ vanishes, $x$ and $y$ become infinite, and the statement of the preceding paragraph is confirmed.

*12. The Kernel of a Section.*—The kernel of a section is the area bounded by the locus of the $K$'s corresponding to a series of neutral axes touching the periphery of the section but never crossing the section. It could be located with the help of Equations 7 and 18 without difficulty. Its main interest lies in its defining an area within which a $K$ must fall in order that the unit-stress may be of the same sign throughout the section. It is interesting, too, in that its radii vectores are lengths which, for any $\lambda$, need only to be multiplied by the area of the section to give $S'$ and $S''$ for that $\lambda$. These lengths would have to be called + if on the opposite side of $K$ from $G$, and *vice versa*. The kernel is then a figure with sides respectively parallel to the $S$-polygon, but on opposite sides of $G$, but unlike the $S$-polygon in being geometrically an actual surface and to the same scale as the section.

The kernel will be established if the $K$'s be found for the neutral axes coinciding with the sides of the circumscribing polygon of the figure. For each such side considered as a neutral axis there will be a $K$ which will be an apex of the kernel. In the light of the preceding paragraph, the co-ordinates of the kernel apex corresponding to any such side, $AB$, may be easily written by reversing the signs in Equation 16 and by dividing the second member by $A$. Accordingly,

$$\left.\begin{aligned} x_{ab} &= -\frac{(x_a - x_b)J - (y_a - y_b)I_y}{A(x_a y_b - x_b y_a)} \\ y_{ab} &= -\frac{(x_a - x_b)I_x - (y_a - y_b)J}{A(x_a y_b - x_b y_a)} \end{aligned}\right\} \quad \ldots\ldots\ldots (19)$$

are co-ordinates of a kernel apex corresponding to $AB$. If $AB$ fall out parallel to the $X$-axis, these expressions become

$$\left.\begin{aligned} x_{ab} &= -\frac{J}{A y_a} \\ y_{ab} &= -\frac{I_x}{A y_a} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots (19')$$

and, if parallel to the $Y$-axis, they become,

$$\left.\begin{aligned} x_{ab} &= -\frac{I_y}{A x_a} \\ y_{ab} &= -\frac{J}{A x_a} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots (19'')$$

expressions paralleling Equations 16′ and 16″.

The kernel and the circumscribing polygon of the section are related to each other in such a way that if the $K$ travel along the

one, the corresponding neutral axes will roll around the other, meaning, by that, that they will coincide with side after side of the other polygon, and, pivoting about the apices of the other polygon, will assume all intermediate positions possible without crossing the surface of the polygon.

The continental writers have given much attention to the kernel, but its practical usefulness is so slight, compared with its close kin, the *S*-polygon, that further description of it need not be given here. The preceding section is here given primarily in preparation for the following section.

*13.—The S-Polygon and W-Fläche Compared.*—The *S*-polygon arrived at in the foregoing was the result of an independent attempt to establish the *W*-Fläche of Professor R. Land, of Constantinople.

The only difference between the two lies in the fact that the sides of the two polygons for a given $m$ lie on opposite sides of $G$, making the *W*-Fläche just like the kernel with all its dimensions multiplied by $A$. The writer believes that the maintenance of this distinction, even at the expense of losing the closest possible similarity with the kernel, is worth while. The relations with the kernel will be of little importance in practice, and it seems natural, and hence conducive to accuracy in computation, to call the radius vector positive rather than negative when measured on the same side of $G$ as the point the stress of which it determines. The radius vector will then come to be a kind of pointer starting from the natural origin, $G$, toward the portion of the cross-section to which it belongs. This is a valuable safeguard against confusion, especially as the diagram is one the use of which is within the comprehension of computers of very moderate experience. Finally, for all sections symmetrical about $G$, such as I's and Z's, the *W*-Fläche and *S*-polygon would be indistinguishable except in the lettering. Only for sections like C's, and T's would the difference appear.

*14.—Closing Remarks on the S-Polygon.*—The *S*-polygon is a graphic exhibit of the values of $S$ leading to the extreme unit stresses in the section for all possible inclinations of the plane of loads. It is subject to the advantages and disadvantages of graphical work. It is of the greatest possible simplicity in use, but the measurement of the radii vectores to a high degree of precision may be difficult. A degree of precision quite sufficient for structural designing, however, is easily obtained. Extreme accuracy is rarely justified in practice, considering among other things the uncertainty as to the actual magnitude and inclination of the loads, the inevitable variations of the rolled shape from the nominal section, inaccuracies in construction and erection, and the doubt whether the principle of linear distribution of stress is rigorously applicable. Such considerations make it certainly justifiable to ignore the

minute effect of the rounded fillets and corners of the familiar shapes.

If, for any reason, the computed value of $S$ be required, it can easily be found by substituting the proper $x$, $y$, and $\lambda$ in Equation 11. In fact, a numerical table could thus be computed for as small variations in $\lambda$ as desired, which would parallel the graphic $S$-polygon. Such tables have been published in Germany for some of the German standard rolled sections.

Finally, the $S$-polygon should be observed to be bounded by lines the radii vectores of which for all values of $\lambda$ have a significance. Radii vectores for points in these lines produced measure values for $S$ which, upon insertion in Equations 13 and 14 will give correct values for the particular point, $m$, to which the $S$-line belongs, and the particular $\lambda$. The portions of an $S$-line between two successive apices of the $S$-polygon are of special importance simply because they mark out the limits of $\lambda$'s for which an extreme fiber stress will result from the corresponding low values of $S$.

In closing, the writer wishes to express his obligations to Bruce Borland, Jun. Am. Soc. C. E., who performed most efficiently the exacting task of computing Table 2; and Messrs. H. E. Norton, S. B., J. R. Nichols, and H. W. Telford, S. B., who have assisted in various ways in the preparation of this paper.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## THE CONTROL OF HYDRAULIC MINING IN CALIFORNIA BY THE FEDERAL GOVERNMENT.

By William W. Harts, M. Am. Soc. C. E.*

To be Presented May 2d, 1906.

As far back in the past as history takes us, the search for gold has had a passionate interest for mankind. The same zeal that animated the Argonauts who accompanied Jason in his quest of the Golden Fleece, the same patience and perseverance that urged on the searchers for the philosopher's stone, the insatiable greed for quickly acquired wealth that sent the Spanish conquerors to the New World, are even in this day driving men to deeds of daring and adventure at the farthest ends of the earth.

The richness of the treasure discovered in California a generation or more ago seems almost fabulous. Gold fields that yielded in a single year more than $81 000 000, and since the first discoveries have produced up to date more than $1 414 000 000, have filled the minds of an army of miners, from that day to this, with that fever for gold which, once acquired, seems never to relax its hold on its victim.

* Captain, Corps of Engineers, U. S. Army.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Scarcely a stream of the western slope of the Sierras but held in its gravel bed quantities of this precious metal, and when all these had been exhausted it was found that enormous wealth could be extracted from the old gravel beds of the prehistoric rivers, those of the tertiary age. To wash through sluice boxes in the quickest time possible these vast quantities of gravel, in order to secure the gold contained, was the eager effort of thousands of men. Millions of cubic yards of these old gravel deposits were thus displaced every year, and washed into the streams and watercourses.

The State of California, not realizing or not caring that some day this might lead to much trouble, assisted the miners in every conceivable way. The right of condemnation of private property for rights of way for mining ditches was granted to the miners, the use of the streams to carry away the tailings of the mines was at one time authorized by legislation, and even the Federal Government, on whose public lands these mines were mainly located, not only made no charge for the privilege of extracting the gold, but even authorized the miners to take up claims without charge, in which they could have a temporary possessory right, protected by law as long as they worked their ground.

It is no small wonder that little thought was given to injuries which might be caused by these operations.

The topography of the Sacramento and San Joaquin Valleys is peculiar, and any interference with the outflow of the floods of these rivers is certain to aggravate a condition already a very troublesome one by nature. Along the flanks of these rivers for miles are rich areas, sometimes several miles wide, which are overflowed each year because of the inability of the rivers to carry off the floods caused by the spring rains and melting snows. For months these rich lands are under water. As the population of the valleys along the rivers increased, a growing hostility arose toward the miners who, it was believed, were mainly responsible for these conditions. Thus arose the historic contention between the miners on the one hand and the valley people on the other, which led to much bitterness of feeling in later years. Its settlement has occupied the minds of many engineers and legislators for years, as well as the time of many lawyers and judges. The end is only now barely in sight.

*The Debris Problem.*—The problem of what to do with the debris

resulting from years of unrestricted hydraulic mining has thus vexed the people of California for upwards of a generation. In the fierce and bitter conflict between the mining interests of the mountains on the one hand, and the interests of the agricultural regions on the other, which has been carried on for more than thirty years, the industry of hydraulic mining was finally completely vanquished. The decisions of the Courts, and their injunctions, had put an end by about 1880 to a form of mining activity in which more than $100 000 000 were said to have been invested at that time, and from which the State of California had originally derived most of its claim to the attention of the world. These decisions and injunctions against hydraulic mining were based on the injuries caused by the tremendous inundation of mining detritus over the farming lands and river beds of the valleys of the central part of the State, and on the constitutional right of the owners of this property to be protected from such injuries.

It cannot be denied, however, that the discovery of gold in California in 1848 gave a stronger impetus to the growth of the State than any other single occurrence before or since. By 1849 there were 100 000 miners engaged in washing the gravel of the river beds of the Sierras. Where a sparse and scattered population had worked out a more or less precarious existence, the discovery of gold caused mining camps first and then flourishing towns to spring up as if by magic. As these grew, the mining industry was followed by the farmers, orchardists and ranchers who settled later in the rich valleys of the Sacramento and San Joaquin Rivers. To save their farms from inundation caused by raising the flood plane of the rivers, and to prevent the bottom lands from being ruined by the accretion of gravel and debris from the mines in the mountains and foothills, legal remedies were resorted to by the valley people, and by about 1880 the once enormous industry of hydraulic mining had been successfully throttled by the injunctions of the Local and Federal Courts.

The feeling between the miners and the valley people became acute, and much bitterness resulted. The State of California had extensive investigations made, but found it could not cope with the difficulty. The Federal Government was then appealed to, and examinations were ordered by Congress in 1880 and again in 1888.

The former was made and a report submitted by Colonel G. H. Mendell,* Corps of Engineers, U. S. Army. The latter was made by a board of three officers consisting of Lieutenant-Colonel Benyaurd, Major Handbury and Major Hauer, all of the Corps of Engineers.† On the report of this board, Congress passed in March, 1893, a mining law which has been since known as the Caminetti Act, from the name of its proposer in Congress. This Act was ostensibly for the protection of the navigability of the Sacramento and San Joaquin Rivers, by preventing them from being filled with mining debris and their depths thus reduced to a point where free navigation would be impossible. It was fervently hoped by those interested in mining in California that the application of the law would be far wider in its benefits and give them the long-sought privilege of operating their mines without hindrance. This law created a Federal commission to regulate hydraulic mining in such a way as to prevent any injury to navigable waters, with ample power to stop all such mining until satisfactory impounding facilities for its detritus were provided by each mine.

The constitutionality of such an enormous interference with the interior affairs of one of the States of the Union as was embraced in this law was based on the provision of the Constitution of the United States assigning to the Federal Government the duty of regulating the commerce between States, and incidentally of protecting the navigable highways.

It was presumably understood in Congress that the steps necessary to protect the interests of navigation from the mining debris evil would necessarily protect all the agricultural interests, as the greater includes the less, so that if the engineers in charge could devise a method which would protect satisfactorily the navigability of the rivers affected, the other questions involving private rights would solve themselves. The depths of the rivers being affected so quickly, there was thus afforded a delicate test of injury. Any mining that would cause no appreciable shoaling in the navigable rivers could scarcely be of any injury to any other interests. If the navigability of the rivers was protected, therefore, the problem that had been of such long standing could be soon settled. This law, it was

* Ex. Doc. 76, House, 46th Cong., 3d Session.
† Ex. Doc. 267, House Reps., 51st Cong., 2d Session.

thought, would thus permit the resumption of hydraulic mining under such restrictions as might be necessary to protect the rivers.

The Act provides for a Federal board of three engineer officers of the army, appointed by the President and confirmed by the Senate, to be called the California Debris Commission. It became their duty under the law to devise plans that would permit hydraulic mining to be resumed, under sufficient restrictions to prevent injury to the lower rivers and the land lying adjacent thereto. The Commission's jurisdiction was limited to the water-shed of the Sacramento and San Joaquin Rivers, but within these limits all hydraulic mining was prohibited except with the license or permit of this Commission. A maximum penalty of $5 000 fine and one year's imprisonment was imposed for violation of the Act.

The Commission was directed also to devise projects that would improve the navigability of the rivers above named and their tributaries, protect their banks against encroachment and damage from mining debris, and restore, as far as required by the needs of navigation, the navigability of the rivers as it existed in 1860.

What has been accomplished by this Commission since its organization is the subject of this paper.

*Description of the Mining Region.*—To understand fully what was assigned to the California Debris Commission and the wide scope and difficulty of its work, the geography and topography of the State of California must be considered briefly in connection with the flow of mining debris.

The entire central portion of the State is inclosed by mountains and consists of an elliptically shaped valley about 450 miles long and 40 miles wide, embracing about 18 000 sq. miles. It is hemmed in by the Coast Range on the west and the Sierras on the east, and is drained by the Sacramento and San Joaquin Rivers, which empty into the Pacific Ocean through San Francisco Bay. All the water falling on the areas of the water-shed of these rivers must pass into the Pacific Ocean through one mouth, about a mile wide at its narrowest point, called the Golden Gate.

The flat portion of the valley embraces about 4 769 sq. miles, where the annual rainfall is about 18 to 20 in.; the Sierra slope, with elevations as high as 11 000 ft., has an area of about 8 843 sq. miles, where the average rainfall varies from 24 to 102 in.; the slope of the Coast

Range has an area of 3 075 sq. miles, with a rainfall of something less than the Sierra slope, whereas the Shasta region on the north, having elevations of more than 14 000 ft. and an area of 5 616 sq. miles, has a rainfall ranging from 30 to 110 in. The average rainfall over the entire water-shed of the Sacramento Basin, of about 26 187 sq. miles, may be averaged at about 30 in.*

Practically all this rainfall is during the winter months and in the early spring, so that the warm rains and melting snows together frequently cause excessive floods. The watercourses in their upper portions are all mountain torrents. It thus happens that every spring the Sacramento River is required to carry off floods far beyond the capacity of its bed.

The superficial area of the channel and slough surface is only 38 sq. miles, out of a total of 4 769 sq. miles of the level part of the valley, and the fall in surface slope is very limited in the lower portions of the river. It has been estimated that, with an annual precipitation of from 30 to 40 in., there will be an area of about 1 700 sq. miles, more or less, flooded every spring when a warm rain sets in after heavy snows.†

It is very evident that the local conditions have for ages, if not always, prevented the Sacramento River from discharging its flood waters promptly. Furthermore, for ages the well-known erosive action and leveling tendencies of all rivers have been at work cutting down the mountains and hillsides and filling up the lower river reaches and the bays. Much of the Sacramento Valley has unquestionably been formed in this way, and this action is doubtless still in progress. It seems more than likely that Suisun Bay is all that is left of a large inland sea, the waters of which at one time probably washed the lower slopes of the Sierras.

The denudation of various valleys by natural causes in different parts of the world progresses at different rates, and it is unfortunate that no definite records are available for the Sacramento water-shed.

Observations on the quantity of sediment carried by various rivers in various lands indicate that the time required by natural agencies to remove an average thickness of 1 ft. of rock in each of the several drainage basins is as follows:

* "Physical Data and Statistics of California," by William Ham. Hall, M. Am. Soc. C. E.

† *Transactions*, Technical Society of the Pacific Coast, February and March, 1887.

| | | | |
|---|---|---|---|
| Danube | Basin | 6 846 | years. |
| Mississippi | " | 6 000 | " |
| Nile | " | 4 723 | " |
| Ganges | " | 2 358 | " |
| Rhone | " | 1 528 | " |
| Hoang Ho | " | 1 464 | " |
| Po | " | 729 | " |

Applying the Mississippi rate to the Sacramento River, it would indicate a removal of about 5 600 000 cu. yd. of sediment per annum; at the Po rate it would indicate 43 000 000 cu. yd. The natural conditions of the Sacramento Basin resemble those of the Po more than those of the Mississippi. It is stated as probable that the annual sediment moved by natural causes is somewhere between the rates of these two rivers, that is, between 5 600 000 and 43 000 000 cu. yd. per annum for the Sacramento Basin.*

Nearly all this natural wash is carried into the lower sections of the tributary rivers, some to be transported into the Pacific Ocean with the tidal currents, some to settle on the shoals and tide flats around San Francisco Bay and some to add to the already gorged condition of the river channels.

We thus see that for probably thousands of years natural agencies have been at work filling up the navigable rivers and encroaching on the area of San Francisco Bay. These natural agencies, already promising certain disaster to the navigable capacity of San Francisco Harbor at some far-distant day, were assisted at an enormous rate by the work of Man, for there were recently added human agencies that rendered more complicated an already too complex situation. This was the removal by hydraulic mining of millions of cubic yards of gravel and sand from their location on the western slopes of the Sierras and the washing of this material into the cañons and tributaries of the Sacramento, Feather, American and San Joaquin Rivers.

*Hydraulic Mining Methods.*—Gold was discovered in California in 1848 during the construction of a mill race at Coloma, near Georgetown, purely by accident. The news spread rapidly, and in 1849 there followed an army of 100 000 miners, who soon washed out

* Annual Report, Chief of Engineers, U. S. Army, 1882.

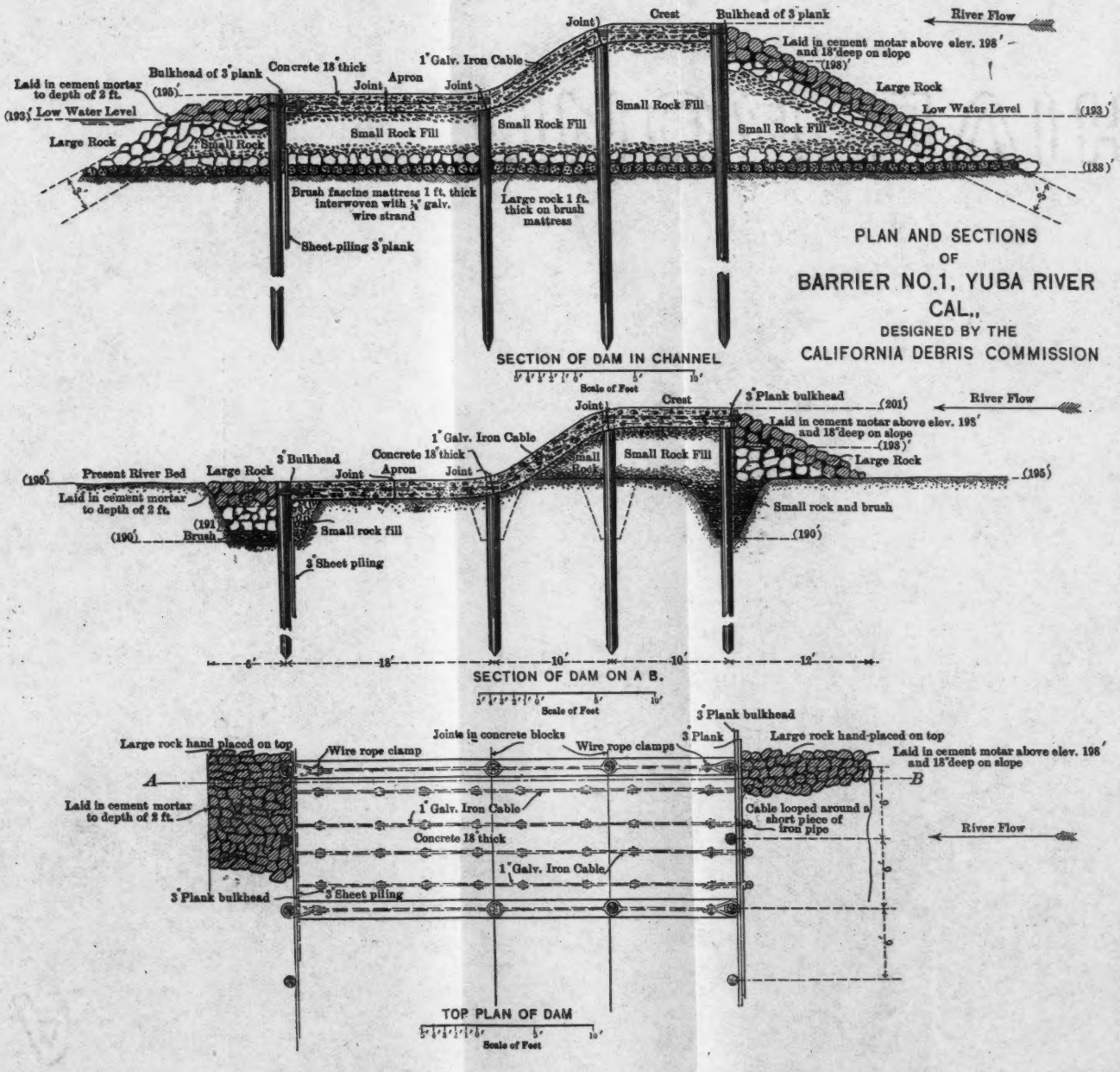
all the accessible gravel lying in the beds of the small creeks and rivers.

The hand-pan, in which only a small quantity of gravel at a time could be washed, gave way early to rockers of larger capacity, and these to sluices where riffles caught the gold, after being washed and separated by the action of flowing water, brought in ditches, sometimes for great distances. It was only a step further to the use of hose and nozzles, and then to steel pipes and monitors for directing powerful streams against the tertiary gravel banks of higher elevations. The streams are used under pressure to break down the banks, and the water carries off the gravel through the sluice boxes, where the gold, by virtue of its high specific gravity, is caught in riffles of various kinds.

This method was invented by a native of Connecticut, and dates from 1852. It dispenses with many men and is a cheap and quick method of excavating gravel banks. The cost, in favorable situations, has been stated to have been as low as 3 to 6 cents per cu. yd. Nozzles as large as 9 in. in diameter have been used, pressures as high as that due to 400 ft. head, and quantities as great as 3 500 miners' in. (about 87 cu. ft. per sec.) in a single stream. The excavating power of these large streams is enormous.

The engineering features connected with these early mining operations are full of interest even now. The difficulties were tremendous in building mining ditches carrying several thousand inches of water for sometimes 40 and 50 miles along the crests of ridges and over deep gulches in wooden flumes, all to bring the quantity of water necessary to mine the gold, at an elevation sufficient to give the pressures that were indispensable. In securing outfall at the mines sufficient to remove the debris while mining, tunnels of great length, in rock, were also often necessary. These operations were all on a scale but little realized by those who have not visited the mining regions.

*Extent of the Damage.*—The quantity of gravel which can be moved in 24 hours by each miners' inch of a stream is called its "duty." This depends on the character of the bank, and varies from ½ cu. yd. to 6 cu. yd., with an average of about 3 cu. yd. This duty, with an approximate knowledge of the total quantity of water used in a season throughout the entire mining field, gives some


Joint
Crest
Bulkhead of 3" plank
River Flow
Laid in cement motar above elev. 198' and 18' deep on slope
(198)'
1" Galv. Iron Cable
Bulkhead of 3" plank
Concrete 18" thick
Laid in cement mortar to depth of 2 ft.
(195)'
Joint
Apron
Joint
Small Rock Fill
Large Rock
Low Water Level
(193)'
Small Rock Fill
Small Rock Fill
Small Rock Fill
Large Rock
Low Water Level
(193)'
(188)'
Brush fascine mattress 1 ft. thick interwoven with ¾" galv. wire strand
Large rock 1 ft. thick on brush mattress
Sheet-piling 3" plank
PLAN AND SECTIONS
OF
BARRIER NO. 1, YUBA RIVER
CAL.,
DESIGNED BY THE
CALIFORNIA DEBRIS COMMISSION
SECTION OF DAM IN CHANNEL
Scale of Feet
Joint
Crest
3" Plank bulkhead
(201)
River Flow
Laid in cement motar above elev. 198' and 18' deep on slope
(198)'
1" Galv. Iron Cable
Concrete 18" thick
3" Bulkhead
Present River Bed
Large Rock
Joint
Apron
Joint
Small Rock
Small Rock Fill
Large Rock
(195)'
(196)'
Laid in cement mortar to depth of 2 ft.
Small rock and brush
(191)'
Brush
(190)'
Small rock fill
3" Sheet piling
(190)'
6'
18'
10'
10'
12'
SECTION OF DAM ON A B.
Scale of Feet
3" Plank bulkhead
Large rock hand placed on top
Joints in concrete blocks
Wire rope clamp
Wire rope clamps
3" Plank
Large rock hand-placed on top
Laid in cement motar above elev. 196' and 18' deep on slope
A
B
Laid in cement mortar to depth of 2 ft.
1" Galv. Iron Cable
Cable looped around a short piece of iron pipe
River Flow
Concrete 18" thick
1" Galv. Iron Cable
3" Plank bulkhead
3" Sheet piling
TOP PLAN OF DAM
Scale of Feet

idea of the quantity of material dislodged annually. In this way it was estimated in 1880 by the State engineers that 53 404 000 cu. yd. of gravel were washed from their banks into the cañons and rivers of the Sacramento Basin. Much of this material was coarse, and was not carried far, but most of the fine material was unquestionably taken down by the first freshet, to be added to year after year, and carried farther at each high water.

Sediment observations of the water of the Sacramento River were made in 1880, and deductions from them indicated that 18 100 000 cu. yd. were brought down that river in suspension that year, of which amount 4 900 000 cu. yd. were assumed to be the proportion due to natural wash and 13 200 000 cu. yd. that due to hydraulic mining. Of the total, 2 100 000 cu. yd. were estimated to have settled in the overflowed basins along the river, leaving 16 000 000 cu. yd. that were carried in suspension past Sacramento and down into Suisun and San Francisco Bays. Of this amount (16 000 000 cu. yd.), it is assumed that 11 100 000 cu. yd. is the proportion due to hydraulic mining. Deducting this 11 100 000 cu. yd. from the total amount excavated by the hydraulic process (53 404 000), as ascertained by the "duty" of hydraulic streams and referred to above, we find that the remainder, 42 304 000 cu. yd. must have been left behind in the numerous cañons and tributaries of the Sacramento and San Joaquin Rivers as a result of the mining operations of a single year.*

These conclusions are based on what now appears to be insufficient observation, and the reference to them here is mainly intended to give an indication as to the enormous extent of the debris problem. A visit through the mining regions, for example, from Nevada City to Dutch Flat, would dispel any doubts in anyone's mind that the denudation by this means was enormous.

The damage done to the streams and lower country is as palpable and manifest to anyone who has visited the Yuba, the Bear and American Rivers as is the extent of denudation.

The vast quantity of debris now lying in the river-beds has been distributed along the watercourses in accordance with the well-known laws of water transportation. Much of it was undoubtedly left where new conditions of flood would move it again to a new

* See Report, State Engineer, 1880.

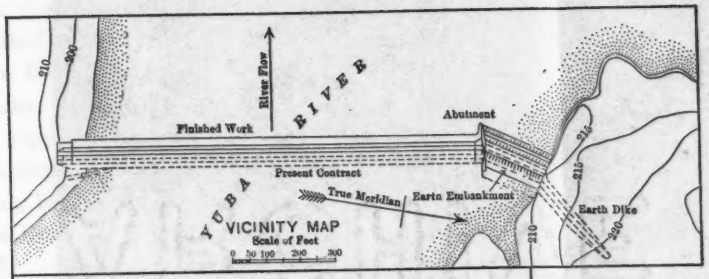
location lower down. It thus seems to be plain that the enormous quantities of tailings in the beds of the cañons and streams are not permanently located, but are only awaiting an opportunity to move to a new location whenever the water velocities of the stream are favorable. The injury once done still exists as a menace for the future, and will continue to exist until conditions of more perfect equilibrium are reached. Surveys recently made indicate that between 1899 and 1904 an addition of more than 15 000 000 cu. yd. was lodged in the bed of the Yuba River from these old deposits.

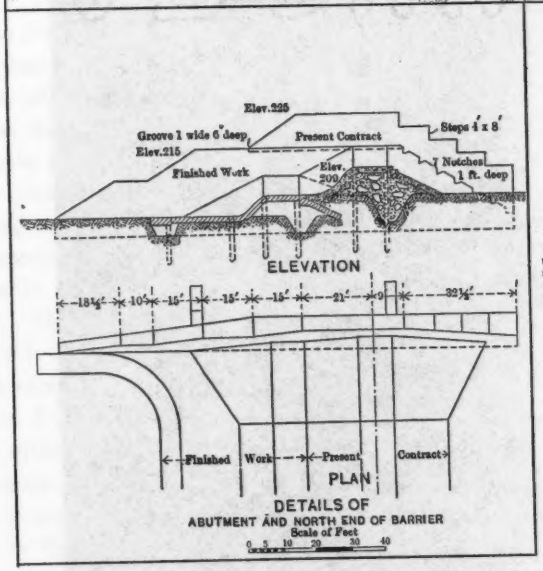
The low-water plane of the Yuba River at Marysville was raised 15 ft. between the years 1849 and 1881.* The citizens of Marysville, in order to protect their town from the damage due to floods occasioned thereby, built levees around the city, which were added to from time to time as required. These levees were continued up to Daguerre Point, about 11 miles, on the north bank. This necessitated levees on the other, or south side, of the river, to protect the adjoining agricultural lands, and thus grew up an extensive levee system which is now maintained at great expense. The lower river, from a narrow mountain stream in 1850, is now filled with sand and gravel so that its bed is nearly 3 miles wide in places, with an average width of about 2 miles. This abnormal width, lying between the lines of levees, extends up the river from Marysville to Daguerre Point, in all about 9 miles. About 25 sq. miles are covered with mining debris. The depth of fill varies from about 7½ ft. at Marysville to 26 ft. at Daguerre Point and 84 ft. at Smartsville. A short distance east from Marysville the bed of the river is now 13 ft. above the level of the surrounding farms. It is plain that any accident to the levees near Marysville would mean a disaster to the town.

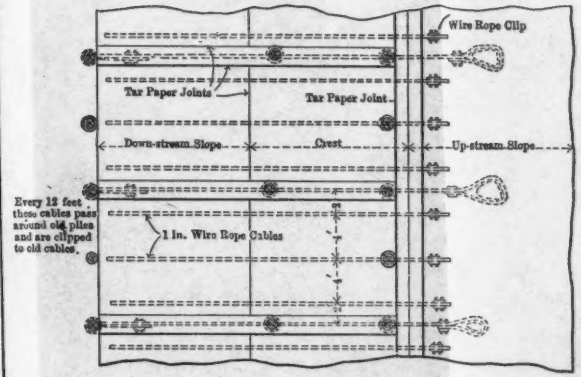
The quantity of material lodged in the river due to mining has been variously estimated at from 71 000 000 to 700 000 000 cu. yd., but it seems safe to say that there are now upwards of 333 000 000 cu. yd. in the bed of the lower Yuba. This material varies in character from cobbles, near Smartsville, to an impalpable powder near Marysville, being distributed along the river-bed from coarse to fine as the slopes diminish. These slopes decrease from about 15 ft. per mile near Smartsville to about 5 ft. per mile at Marysville.

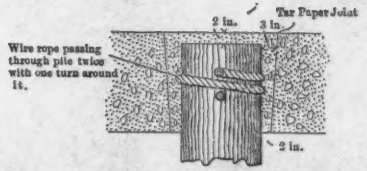
* Appendix MM, Annual Report, Chief of Engineers, U. S. Army, 1882.

# PLAN AND SECTIONS
OF
SECOND STEP
# BARRIER NO.1 YUBA RIVER CAL.
DESIGNED UNDER THE DIRECTION OF THE
# CALIFORNIA DEBRIS COMMISSION

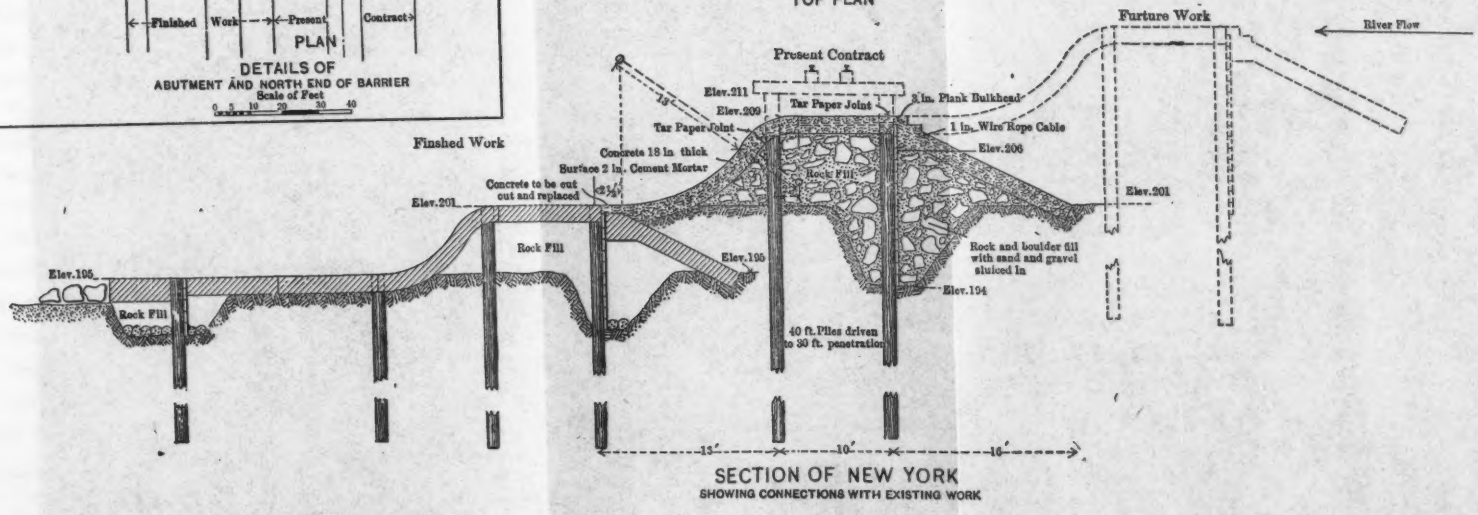



DETAIL OF PILE HEAD
SHOWING CABLE FASTENING END JOINTS
BETWEEN CONCRETE BLOCKS




SECTION OF NEW YORK
SHOWING CONNECTIONS WITH EXISTING WORK

Not even a faint conception can be had of the vast body of mining material in this river, without seeing the river-bed at low water.

The Bear River shows greater depths of mining detritus than the Yuba, but the quantities are not as large, the cañon of the Bear being steeper and narrower. The best information available leads to the conclusion that the Bear River is filled 150 ft. deep at the crossing between Little York and You Bet. The quantities lodged in the Bear River were roughly estimated at 66 000 000 cu. yd. in 1891.*

The Feather, the American, Consumnes, Calaveras, Mokelumne and other tributaries of the Sacramento are all, in greater or less degree, affected in the same way.

The Sacramento River itself shows unmistakable signs of considerable fill, largely due to mining detritus. Since 1849 the low-water plane at Sacramento has been raised about 7½ ft., causing a reduced carrying capacity for its flood waters and requiring property owners to build levees to protect themselves from floods. The available depth for navigation, however, has remained about the same. The quantity of debris in the river is estimated at 108 000 000 cu. yd.†

A comparison of charts shows that the bar across the entrance to San Francisco Bay has not deteriorated noticeably, nor the channels within the bay diminished in depth, but shoaling on the areas along the flanks of the channels is perceptible, and the channels are slowly narrowing. In Suisun Bay the area of shoals is increasing, and at Carquinez Straits there are indications of the formation of large deposits.‡

*Duties of the Commission.*—Such, then, was the condition that confronted the first Commission in 1893. To check the injury to navigable streams at once, to prepare plans for the improvement of their navigability by restraining works, and to rehabilitate hydraulic mining as far as practicable, were the duties imposed upon this Commission by the Act. The supply of new detritus from hydraulic mines had by that time been mainly, if not entirely, stopped by injunctions of the Federal and State Courts, prohibiting all such mining, but the flow of debris was still continuing, due to the washing

* Appendix MM, Annual Report, Chief of Engineers, U. S. Army, 1882.
† Ex. Doc. No. 267, House, 51st Cong., 2d Session.
‡ Appendix MM, Annual Report, Chief of Engineers, U. S. Army, 1882.

down at every flood of a part of the enormous quantities already stored in the upper river reaches and the tributary eañons. The damage once started could not be wholly overcome by injunctions.

In designing restraining works there was no precedent nor previous experience from which valuable lessons might be learned by the new Commission, but everything had to be originated *de novo* as no such condition probably exists elewhere in the world.

In addition to all this, the miners were clamoring for permission to resume mining under the new law, insisting that they be told of the restrictions so that they might comply with the law, if found practicable, and be permitted to resume their business legally.

The first efforts of the Commission were thus directed to making examinations of the mining regions, in order to see what relief could be given the miners.

It was found in many cases that the construction of dams in the cañons below the mines would store all the material that would be moved, and in some cases there were old hydraulic mine pits that could be filled with detritus without damaging the lower rivers. Other expedients were studied, but the method of using dams across the ravines and cañons below the mines was found most satisfactory for the general case.

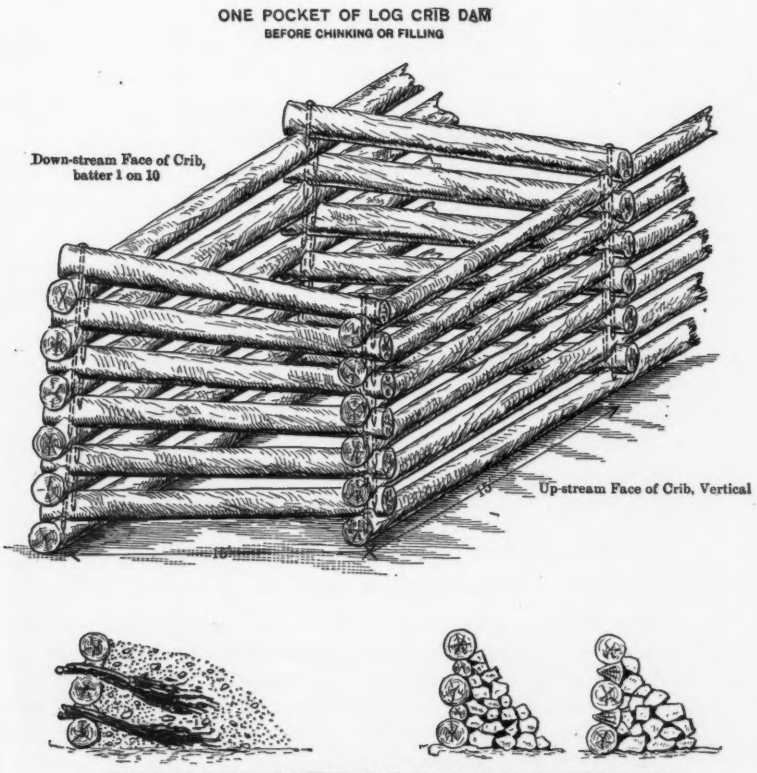
*Impounding Dams.*—Various kinds of dams were tried: stone, earth, brush and rock, log-crib filled with rock, and many others. After twelve years of experience it has been found that the usual small mine where impounding dams can be used will need one of two general types—either log-crib dams or brush dams.

There are special cases, of course, when other kinds of dams are needed, but these two types are most common for the smaller mines, and printed specifications for these dams with a cut explaining their construction has been prepared by the Commission.

The log-crib is the usual type. It consists of a "cob-house" crib made of large logs which are notched and drift-bolted together. It is filled with quarried rock and chinked against leakage. This type of dam is seldom built more than 40 ft. high, this being the limit of safety placed by the Commission for the usual case. These dams are very satisfactory for their purpose when well made. As long as they are kept wet they are practically permanent, and in those locations where the logs rot, due to being dry part of the time, the rock

being angular and well bedded in gravel will resist erosion long after the logs have failed to bind the dam together.

The brush dam is less used, as it is permitted usually only when the water-flow over the dam is small, or when the river is diverted






SKETCHES SHOWING METHODS OF CHINKING DOWN-STREAM FACE

FIG. 1.

through a spillway at one end, and only when the slope of the cañon above is slight. These brush dams are not permitted more than 20 ft. in total height.

Figs. 1 and 2, with the specifications and the photographs herewith will show plainly their construction in both cases.

## General Instructions for Log-Crib Debris Dams.

Approved by the California Debris Commission, January 18th, 1904.

1.—The bottom and sides of the dam are to be founded on bed-rock, and the ends of the timbers set into bed-rock wherever practicable, so as to provide a shoulder against which the dam may rest to resist the pressure of the debris when impounded.

2.—The dam will consist of a down-stream and an up-stream wall of logs connected by cross-logs running up and down stream, the walls of cross-logs to be not more than 16 ft. apart.

3.—All logs are to be as large as practicable, and to be well notched and drift-bolted together at crossings.

4.—The distance between the up-stream and down-stream walls of logs is to be not less than one-half the proposed finished height of the dam, and in no case less than 15 ft.

5.—The up-stream wall is to be vertical, and the down-stream wall is to have a slight slope up stream of about 1 ft. in every 10 ft. in height.

6.—The spaces between the logs in the down-stream wall are to be closed by small logs laid inside the dam, or by brush, as shown in Fig. 1.

7.—The dam is then to be filled with stone and chinked with fine brush, leaves, etc., so that while mining is in progress, it will maintain a pool of water at least 2 ft. deep.

## General Instructions for Brush Debris Dams.

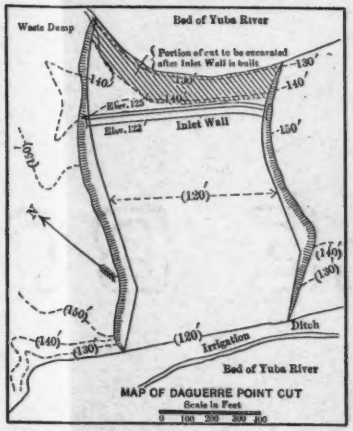
Approved by the California Debris Commission, January 18th, 1904.

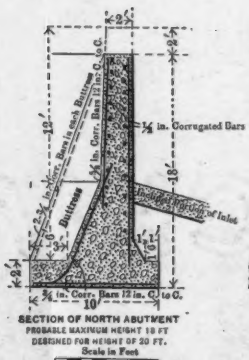
1.—Brush dams should be built of live strong brush at least 10 ft. long. All large limbs should be hacked with an axe, but not cut off, and then bent back to lie compactly. Small twigs and leaves should be left on. The poles used should be not less than 4 in. in diameter and not more than 12 in. The poles should be well trimmed, and as long as practicable.

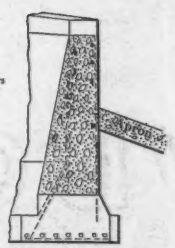
2.—The dam should be built along a straight line, as follows: Level off the foundation. On this lay the brush closely, with the butts in a line and pointed down stream. This should make a thick, compact layer. On top of this layer and at right angles to the brush lay a pole about 2 ft. back from the ends of the butts, which, with other poles like it, should extend entirely across the stream.

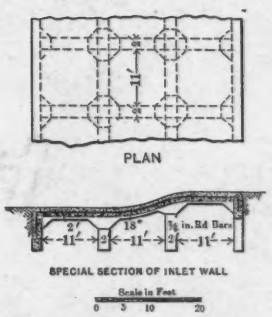
3.—A layer of gravel or small stone is then placed on the layer of brush as high as the thickness of the pole. On this layer of

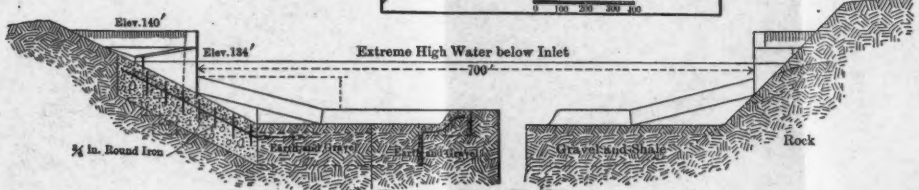
# PLANS FOR INLET WALL AT DAGUERRE POINT CUT, YUBA RIVER, CALIFORNIA, FOR CALIFORNIA DEBRIS COMMISSION

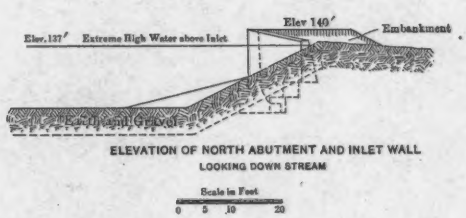


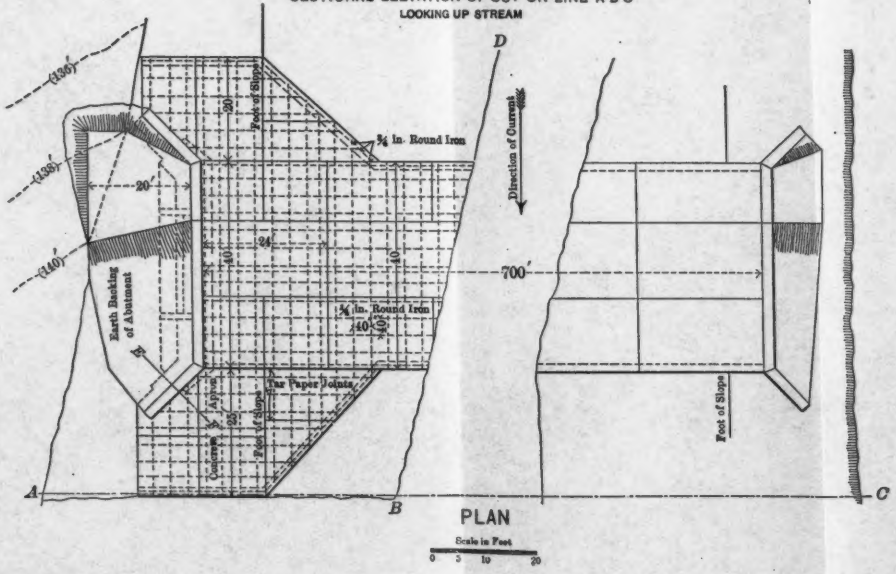



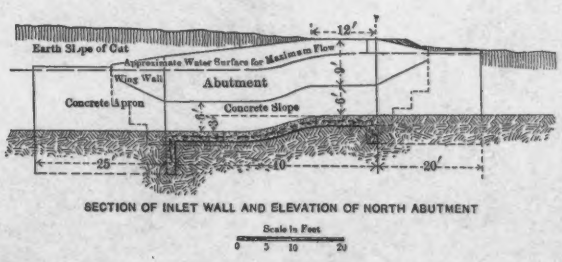



gravel place another heavy, compact layer of brush as before, butts down stream and tips up stream, on which lay another row of poles across the stream. Then place another layer of gravel as before, and so continue until the dam is of the required height. The dam should then consist of alternate thick layers of brush and thin layers of gravel, each two layers of brush separated by a row of poles. See Fig. 2.

4.—The poles should be placed so that each row is somewhat back of the row below, so that the whole down-stream face of the dam when completed will have a slope of about 3 horizontal to 4 vertical, and so that the butts of the brush will be about 2 ft. higher than the tips. Each row of poles should be strongly wired, every 4 ft., to the row of poles below.

5.—The dam must be tightened against leakage, with gravel and fine brush thrown on the tips of the brush, so that, when the

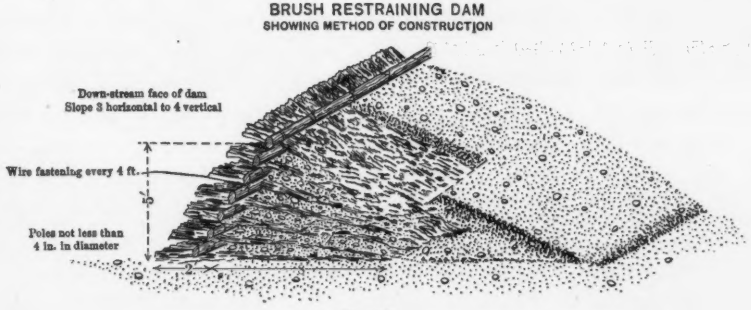



FIG. 2.

mine is being worked, a pool of water at least 2 ft. deep will be always maintained.

*Requirements for a License.*—Before being permitted to mine, under the United States laws, the hydraulic miner must have a license, or permit, from the California Debris Commission. In order to obtain this license, he must submit an application, or petition, on the form supplied by the Commission, in which he states under oath the location and description of his mine, its extent, the source and quantity of his water supply, the dimensions and grade of his sluice boxes, what restraining works he proposes, the precipitation of rain and snow, the drainage area above his mine, and several other items of information which affect the flow of detritus. This application is advertised in newspapers for three weeks, to permit any protests

to be filed with the Commission. If no protests are received, an inspection of the mine and its impounding facilities is made, and the location and kind of restraining dam decided upon in consultation with the owners of the mine. An order is sent by the Commission to construct the restraining works decided upon, and later another inspection is made when the works are completed. If these works are found satisfactory on this second inspection, a revocable license to mine is issued. Monthly reports are then required from the mines thus licensed, showing the quantity of material mined and the condition of the dams.

*Inspections.*—Frequent inspections are made to ascertain whether dams are kept in repair, whether there is always ample storage capacity, and whether any mines are operating without licenses or without dams. For this purpose several employees of the Commission, often a Deputy United States Marshal, are constantly inspecting during the mining season, and members of the Commission visit mines from time to time whenever a special inspection is needed. The cost of these inspections, of advertising applications, and the expenses of keeping the records of the mines, their reports, etc., in the office, are all borne by the United States, the mine owners, of course, building and maintaining at their own expense the restraining works required.

The task of inspecting mines and keeping their records is no small one. The mining area covers about 450 miles in length and 40 miles in breadth of rough and mountainous country which must be covered several times each mining season by the inspectors. This is necessary to prevent illegal operations and to maintain control of the licensed mines. The number of applications for licenses now reaches 727, the greater proportion of which, however, are not now in force. A card index, with lists arranged according to counties and consecutive numbers, is necessary to keep accurate record of the conditions at each place.

Mining without licenses, or even dams, and the use of various tricks to avoid building and maintaining dams are practiced to a limited degree, but it is seldom that legal steps are necessary to stop this sort of illegal operation. Careful and frequent inspections, with occasional warnings, are usually all that is necessary to prevent all illegal mining of any importance.



FIG. 1.—BANK OF A HYDRAULIC MINE (NOT IN OPERATION) IN NEVADA COUNTY, SHOWING GREAT DEPTH OF EXCAVATION.



FIG. 2.—DISHONEST SLUICE, WITH CONCEALED TRAP, PARTLY OPEN, TO PERMIT TAILINGS TO PASS INTO A SIDE RAVINE, INSTEAD OF INTO THE AUTHORIZED SETTLING BASIN.

In this way the debris from hydraulic mining has been regulated so that very little is now added to the old supply. These restrictive measures, unfortunately, have been too great to permit the resumption of hydraulic mining on the large scale formerly followed, but, on the other hand, they have permitted many mines to operate that otherwise would have had to remain idle.

There are now mined nearly 1 000 000 cu. yd. each year, which are stored in the cañons and ravines behind debris dams specially constructed for the purpose. Under the restrictions imposed, the lower rivers are now slowly improving. The Sacramento River is gradually lowering its low-water plane at Sacramento, and the effect of the tide is beginning to increase. Both of these indications are distinctly favorable.

*Protection of the Navigable Rivers.*—The other side of the Commission's duty is the study of the rivers of the Sacramento and San Joaquin systems, with a view to the preparation of plans for the treatment of these streams and their tributaries so that the injurious mining detritus may be kept out of the navigable rivers, and the streams restored to their former condition of navigability as far as may be needed.

The first step, after preventing the operation of mines where debris was not properly impounded, was the treatment of the larger tributaries to prevent the enormous quantities now in their beds from reaching the navigable streams.

In 1881 the State of California built a brush dam in the Yuba and one in the Bear River, with a view to impounding debris up to the crest of the dams. These dams were only a few feet high and were constructed of brush, gravel and sand-bags. They were necessarily founded on the unstable gravel bed of the river. Neither dam withstood the first high water. Both streams have widely varying discharges, the Yuba ranging from about 300 cu. ft. per sec. in the summer and autumn to about 80 000 or 90 000 cu. ft. per sec. during floods. The Bear River varies from about 10 cu. ft. per sec. during the summer low water to an estimated flood discharge of about 15 000 cu. ft. per sec.

With these flood volumes it is evident that any dam to hold, if built on the treacherous gravel of the river bed, must be of considerable strength.

*General Principles of Improvement.*—In undertaking the formulation of a plan for these rivers, the Engineer Officers adopted a general line of work that was believed to be applicable. It consisted of three divisions:

*1.*—The construction of moderately high dams in the foothills where the rivers emerge into the valleys, and where the value of land is not great. These dams, being located where the slopes in the river-bed are comparatively high, were placed there with a view to sorting the heavy material, that will stand on high slopes, from the fine material that will not, thus storing this heavy material where it will be impounded cheapest.

*2.*—Embankments and basins lower down the river, forming settling pools, where the slopes are flatter and where practically all the finer material can be deposited at all except high stages of the river by bringing the flowing water almost, if not entirely, to rest.

*3.*—Training walls in the remainder of the lower river, to confine the flow in selected channels, so that the large quantities of debris now in the river beds, outside these walls, should not be overflowed, and thus could lie undisturbed indefinitely.

After investigating various other plans, it was believed that the application of these principles would hold back all the debris that could be impounded, and would offer the best solution of the problem.

*Yuba River.*—It was decided to commence the work of restraining the debris of the Yuba River, as this stream has suffered more from mining detritus than any other in California, and is causing the most trouble in the navigable rivers. If the difficulties could be surmounted in this stream, the methods found best adapted to the purpose would likely be more easily applied to the other rivers.

After a study of several years, and after extended surveys in which numerous borings were made, a plan was adopted by the Commission and submitted to Congress in 1900. Much credit is due to Mr. Hubert Vischer, Assistant Engineer, whose work on this plan, under direction of the Commission, has been of much value. The plan has since been modified from time to time as the progress of the work rendered necessary. The estimated cost was $800 000, of which the State of California, under the provisions of the Caminetti Act, pays one-half. This project was adopted by Congress and funds appropriated therefor.



FIG. 1.—A BRUSH DAM IN CALAVERAS COUNTY.



FIG. 2.—A LOG-CRIB DAM, WITH SPILLWAY, IN PLUMAS COUNTY.

The project provided for:

*1.*—Barriers across the river just below Smartsville, to hold back the coarse detritus coming from the upper reaches.

*2.*—A cut at Daguerre Point through which to divert the river at high stages, with embankments forming a settling basin for impounding fine material during the remainder of the year.

*3.*—Training walls, about 2 000 ft. apart, extending from Daguerre Point to the Feather River, to confine the flow to a selected channel.

*Barriers.*—The barriers are to be a system of weirs extending across the river, where the banks are high enough to afford large

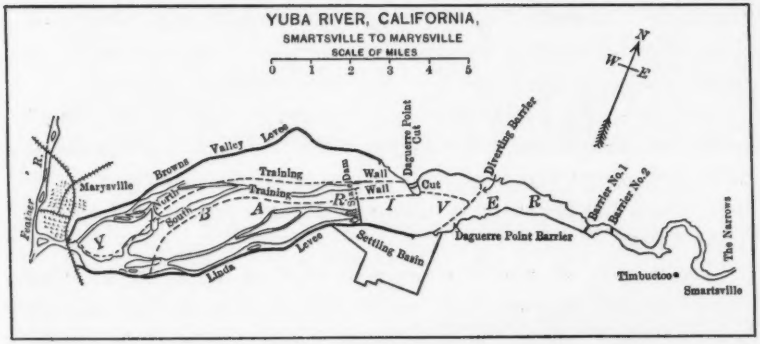



FIG. 3.

impounding capacity, the first located a few miles below Smartsville. This first barrier was the only one estimated for in the present project, but it was to be supplemented by others higher up the river as soon as it was filled, the others to be located and built when necessary.

A dam of brush, rock and gravel was first proposed, with a row of Wakefield sheet-piling 20 ft. deep to protect the toe. It was found impracticable to drive the sheet-piling on account of the coarse and heavy material of the river-bed, and, therefore, this type was abandoned after several hundred feet of it had been placed with much difficulty. This portion afterward washed out during a flood in the winter of 1903-04.

A modified brush barrier was then tried by the Commission. It was a "cob-house" construction of brush fascines forming pens 5 ft.

square with an elevation of 4 ft. above the river-bed. These pens were filled with heavy rock. An apron 20 ft. wide was made of a mattress of brush fascines fastened together with cables. This dam was destroyed by the first high water. The large amount of drift carried by this freshet broke apart the fascines and the dam soon disintegrated.

The design next tried was much stronger. It is anchored to the river-bed with piles, and tied together longitudinally with two timber bulkheads. The first step of this dam, 6 ft. above the river-bed, is comprised of rock fill held in place by concrete blocks weighing about 10 tons each, molded in place over the rock fill, and connected with wire cables embedded in the concrete. Leakage is checked by the timber bulkheads. A broad apron, 20 ft. wide, with a 6-ft. lip, diminishes the scour at the toe, that otherwise might undermine the dam. A sloping up-stream face prevents damage from drift.

It is thus seen that most of the weaknesses of the previous dams have been remedied in the new type. This dam has passed successfully through its first high-water season without any sign of weakness, and is the first dam to withstand a single freshet in the lower Yuba River.

The dam is the first of a series of steps of which the ultimate barrier will be composed and consists of four rows of piles, the two upper intervals between rows being 10 ft. and the interval between the third and fourth rows being 18 ft.

Piles are at 6-ft. centers in the uppermost row, at 12-ft. centers in the two middle rows, and at 3-ft. centers in the lowest row. Every 12 ft. the piles in a tier up and down stream are connected at their upper ends with 1-in. galvanized-wire cable. A timber bulkhead, 3 in. thick, is spiked to the up-stream and another to the down-stream row of piles, and is carried as deep as the water in the river would permit.

Between the first two rows of piles is placed a fill of rock which was brought up to a subgrade, so that when covered by the concrete blocks, 1½ ft. thick, the height of the barrier would be 6 ft. above the average level of the river-bed. Concrete blocks, about 10 ft. square and 1½ ft. thick, are built in place over all this fill, connecting, by a rollerway, with an apron 20 ft. wide resting on the river bed below the dam.



FIG. 1.—A LOG-CRIB DAM IN SIERRA COUNTY, SHOWING LARGE TIMBER USED.

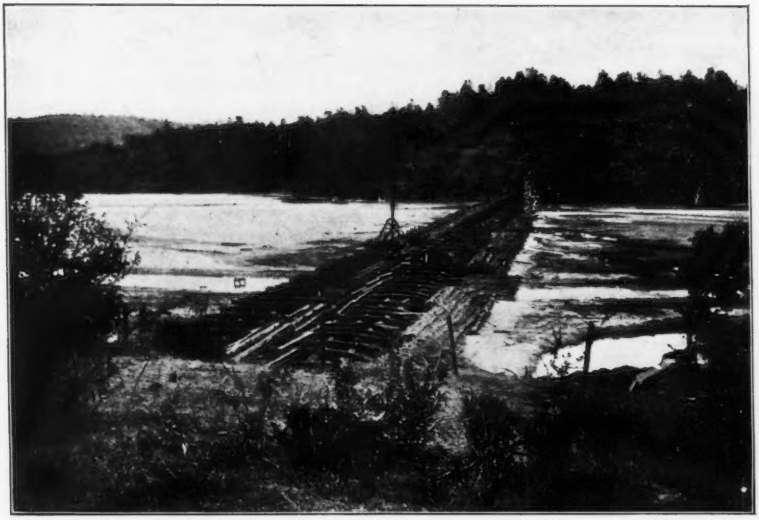


FIG. 2.—A BRUSH AND ROCK DAM ON THE YUBA RIVER, SUBSEQUENTLY DESTROYED BY HIGH WATER.

The up-stream slope is protected by an inclined layer of large rock laid in Portland cement mortar. The concrete slabs of the top surface of the dam and those of the apron are separated from each other by tar-paper joints, and to prevent dislocation by the river currents are connected in the direction of the stream flow with 1-in. galvanized wire cables, 3 ft. apart, embedded in the concrete. The cables connecting the piles referred to above are also embedded in a narrow strip of concrete 18 in. square, which helps bind the heads of the piles together in each tier and separates the large blocks.

Excepting these narrow strips, the concrete slabs rest on the river bottom only, and are not supported on the piles. They are jointed so that they are free to move vertically, the cables acting as hinges.

This was designed to permit the concrete blocks to follow down any considerable scour under the apron, should it occur, and thus prevent any serious damage to the dam due to back-lash.

The weak place in all over-fall dams on poor foundations is, of course, the toe. The rollerway and apron are designed to help to protect the river-bed from excessive and dangerous velocities. In addition, an extension or lip of masonry 6 ft. wide is placed below the apron to carry the water away from the toe, and, if under-scoured, it will break up, fall into the hole and offer protection against further scour. This action occurred near the south bank for a short length during the high water of 1905, and was found to act effectively as planned. In addition, for about 600 ft., the dam at the south end, where the scour was believed to be strongest, was further protected by large rock or rip-rap placed at random. This protection, which may be considered a flexible rip-rap apron, was added to during the next season, making it more than 20 ft. wide entirely across the river-bed.

The south end of the dam is joined to the bed-rock of the river bank, on which the south abutment is founded. At the north end, also, a concrete abutment was built, which was founded on piles, to act as a retaining wall for the earth embankment built later to connect the north end of the dam with the shore. The north shore is composed of compactly cemented gravel through which it was originally planned to have a spillway constructed to carry the river at all stages except flood. During construction, the entire river was

permitted to pass between this abutment and the north shore, before building the embankment, so that the first step was constructed entirely on the dry river-bed. When the time came to close this gap through which the river flowed, it was found to be an undertaking far greater than was anticipated, as there were about 1 200 to 1 300 cu. ft. per sec. flowing around the end of the dam, about three times the flow expected. This flow had to be lifted more than 8 ft. over the completed structure.

The first pile-work placed to close this gap failed on account of the pressure of the water and the serious scour which took place in the bottom while trying to close the opening. Later, more piles were placed in the opening, and, by the liberal use of brush and sand bags, the gap was finally closed.

Much assistance was afforded by an auxiliary dam or levee in the river, ¼ mile long, hastily built to divert the flow over the dam and away from the cut. More than 20 000 sand bags were used in closing this gap, as no rock was available. As soon as closed, the gap was filled with an earth embankment.

The experience with the north bank near the end of the dam has decided the Commission to change the location of the permanent spillway from the north end to the south bank, where the cut will be in rock. This spillway will be 400 ft. wide on the lip and 4 ft. deep, and will be raised as the dam is raised. When completed, it will take a flow of 13 600 cu. ft. per sec. before the dam comes into use, so that the river will be carried around the south end of the dam at all times except for a short period during each year at flood stages. This will make the dam when completed practically permanent and easily maintained.

The first step of the permanent dam having proved so satisfactory, the Commission decided to build the second step during the following low-water season, and contracts were let in May, 1905. This work is now completed. The elevation of the second step is 8 ft., making the total height of the dam 14 ft. The general features of this second step are the same as those of the first step.

In the same way, it is expected to put a step about 8 ft. high on the dam as often as conditions warrant. In this way the ultimate height of the dam (36 ft.) will be reached by successive steps. This method was found advisable, as the amount of work possible in the



FIG. 1.—BARRIER NO. 1, YUBA RIVER, SHOWING METHOD OF CONSTRUCTION.

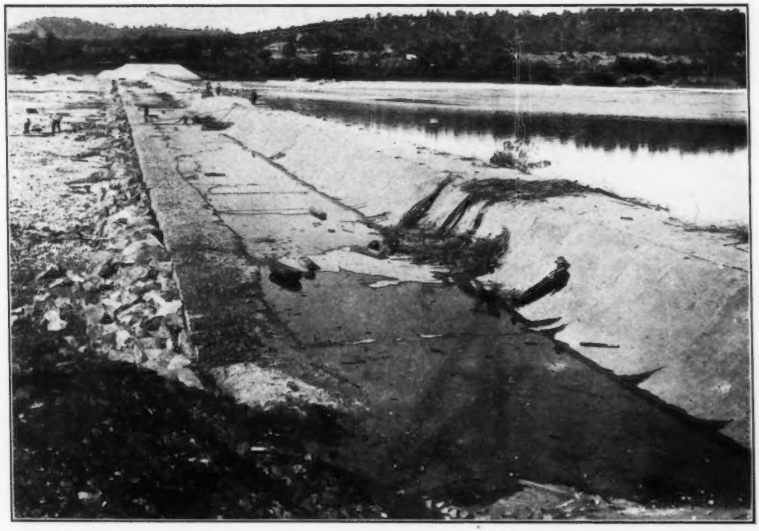


FIG. 2.—FIRST STEP, BARRIER NO. 1, YUBA RIVER, COMPLETED, READY TO TURN THE RIVER OVER THE DAM.

river-bed during the low-water season is limited, and time must be given to the river to fill each step with gravel.

The first step, already built, has been filled with gravel to its crest since the first heavy freshet, and gravel as large as pigeons' eggs has been rolled over the top of the dam for several months. This has given rise to considerable wear of the concrete, in some places more than 2 in. deep during the winter.

It is thus plainly seen that the dam as a whole is a gravel-fill dam sluiced into place by the river itself, the down-stream slope of which is composed of a layer of concrete blocks having a general inclination of about 1 vertical to 3½ horizontal. The concrete overlies a rock fill held in place by a framework of anchor piles and timber bulkheads.

The concrete for this work was made of gravel taken from the river-bed. It was screened and measured in order to get the proportions of the various sizes decided upon. The materials were unusually clean, white quartz sand, gravel and small cobbles. Cobbles were selected that would pass a 2-in. ring and be held by a 1-in. ring, gravel that would pass a 1-in. ring and be held by a ¼-in. ring, and sand passing a ¼-in. opening was used, care being taken to select sand from places in the bed where but little fine material was found. A number of experiments for voids were made, all showing that the interstices in each size varied from 32 to 35 per cent. The average was about 33%, which was assumed to be the average for each size. The proportions used were: 1 cement, 2 sand, 2 gravel, and 4 small cobbles, for the first season's work, and an additional volume of gravel was added for the second season's contract, making the proportions 1, 2, 3, 4. The concrete was hand-mixed in the first year and machine-mixed in the second year, effecting a great saving in cost to the contractors for the later work. A local brand of Portland cement was used. The resulting concrete was thoroughly satisfactory for the purpose. A wearing surface of 1 to 3 mortar, 2 in. thick, was placed over the concrete in the first year, but this wore through in places with the abrasion caused by the gravel which passed over the dam. It was found that the quartz aggregate of the concrete was the best to resist the abrasion, and the surfacing will probably be omitted in the future.

*Cost.*—The first piling was purchased under contract, but driven

by the United States, because it was not believed advisable to contract for this work at first, as the risk was considerable, and it was freely predicted by some engineers that no piles could be driven in the bed of the Yuba River at that place. Excepting delay due to overturning and wrecking the driver twice by high water, this work was carried to completion without notable difficulties, 888 piles being driven with an ordinary land driver equipped with a 20-h. p. Lidgerwood engine and a 3 500-lb. hammer working in 45-ft. gins. The driving was difficult, each pile requiring from 150 to 250 blows. The piles cost from 19 to 23 cents per ft. delivered in Marysville, and 10 cents per ft. to haul to the site of the work, 17 miles further. This made each pile cost about $12. The driving cost $5.02 per pile, making the cost of each pile in place about $17. Including experiments with water-jet and accidents, the cost was $19.74. This price was considered high at the time, but the work under the contractor for the piling of the second step, in the spring of 1905, has exceeded this price. Under contract, the new piling for the second step has cost the Commission 31½ cents per ft. per pile delivered at the site of the work, making each pile cost $12.60. The contract price for driving is $7.60, making each pile under contract cost $20.20 in place.

Portland cement costs $2.785 per bbl. delivered at the site of the work. It was furnished by the contractor during the first season, but by the United States during the second.

The cost of the work on the first step, including the abutment, is shown in Table 1, the prices including placing:

TABLE 1.

| | | | | | |
|---|---|---|---|---|---|
| Excavation | 6 470 | cu. yd. | at | $0.30 | $1 941.00 |
| Lumber | 61 655 | ft., B. M., | at | $40.00 | 2 466.20 |
| Loose brush | 95 | cords | " | 3.50 | 332.50 |
| Large rock | 2 411.75 | tons | " | 2.00 | 4 823.50 |
| Large rock in cement | 1 621.307 | cu. yd. | " | 7.00 | 11 349.15 |
| Small rock fill | 4 251 | tons | " | 1.00 | 4 251.00 |
| Cable | 30 300 | lin. ft. | " | 0.18 | 5 454.00 |
| Concrete | 3 754.2 | cu. yd. | " | 7.50 | 28 156.50 |
| Extra work | | | | | 1 300.19 |
| Total | | | | | $60 073.95 |

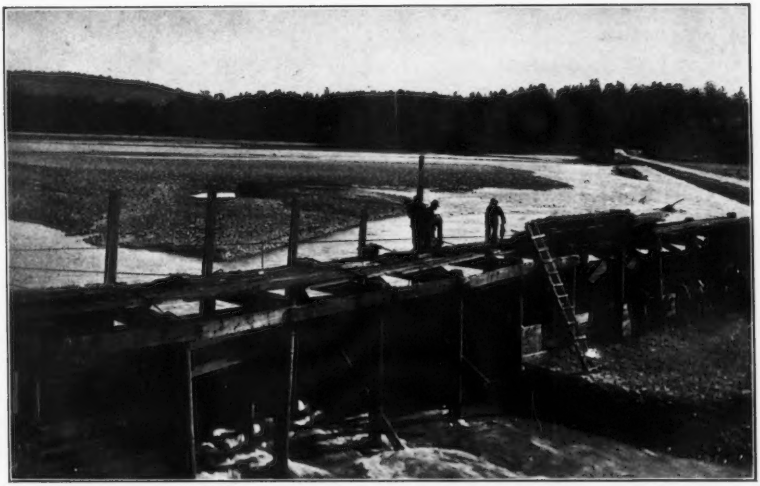


FIG. 1.—FIRST ATTEMPT TO DIVERT RIVER FLOW OVER THE BARRIER. UNSUCCESSFUL.



FIG. 2.—PORTION OF RIVER CHANNEL USED DURING CONSTRUCTION, CLOSED, PREPARATORY TO FILLING WITH EARTH EMBANKMENT.

At the prices given in Table 1 only a small profit was made by the contractor, according to memoranda kept by the engineers during the progress of the work.

The entire dam, including piles, but not the north abutment and embankment, cost, in round numbers, $78 613, or about $63 per lin. ft.

The construction of the first step of the barrier was successful, and its behavior was satisfactory during the high water of the past winter. This enabled the Commission to take up the construction of the second step of 8 ft. higher during the following low-water season. Accordingly, a contract was let in February, 1905, for delivering 400 piles at the site of the work at 31½ cents per lin. ft., this cost being made up of about 21½ cents on the cars at Marysville and 10 cents for hauling them 17 miles to the barrier. A separate contract was let in February for driving the piles at $7.60 per pile. All piles, 335 in number, were driven by June 15th, 1905.

The piles were 40 ft. long, driven to 30 ft. penetration in the river-bed, leaving 10 ft. standing for the step, including a small cut-off.

A contract was let for the main part of the second step in April, and by June 15th, 1905, work was commenced. The main features of the second step are similar to those of the first step, and are shown on Plate VII. The work was carried on without interruption from high water, as had happened twice in constructing the first step, and by November 25th, 1905, had been completed. In carrying on this work, the entire river flow, amounting in the late summer to only about 300 cu. ft. per sec., was thrown into a selected channel at the south end of the barrier, which was protected from scour by brush mattress loaded with rock. This enabled the entire dam, of about 1 250 ft. length, except about 120 ft. at the south end, to be constructed in the dry bed of the river. Upon the completion of the main work, a double row of piles at this south end, specially provided for this purpose, was bulkheaded and then filled with rock. This formed a coffer-dam around the unfinished end of the dam, which thus turned the water over the main dam, permitting the small unfinished section to be built without interference.

A flexible apron of rip-rap rock, 20 ft. wide, was laid across the

river-bed below the toe of the first step to protect the bottom from scour. Rocks weighing from 500 lb. to 2 tons were selected for this portion of the dam, 5 472 tons being used. This will be added to, during each low-water season, as needed. A south abutment was commenced, of which the only portion built was that necessary to provide for foundations for future work. This abutment is founded on rock, and will form a part of the spillway to be built later at this end.

The contract prices and the quantities used for this second step are given in Table 2.

TABLE 2.

| | | |
|---|---|---|
| Excavation..... | 2 985 cu. yd. at $0.75 per cu. yd..... | $2 238.75 |
| Embankment..... | 11 520 " " 0.30 " " ..... | 3 456.00 |
| Bulkhead lumber... | 61 000 ft. B. M. at $25.00 per M..... | 1 525.00 |
| Rock fill..... | 13 223 tons at $0.875 per ton..... | 11 570.13 |
| Large rock..... | 5 409 " " 2.00 " " ..... | 10 818.00 |
| Concrete..... | 4 156 cu. yd. at $4.25 per cu. yd..... | 17 663.00 |
| Wire cable..... | 15 600 lin. ft " 0.15 " lin. ft..... | 2 340.00 |
| Brush mattress..... | 560 sq. yd. " 0.70 " sq. yd..... | 392.00 |
| Sand bags..... | 1 600 at $0.07 each..... | 112.00 |
| Total..... | | $50 114.88 |

Records kept during progress of the work show that the contractors made no profits at these figures.

To the total in Table 2 must be added the cost of cement, 4 100 bbl. at $2.785 per bbl., the cost of piles, $6 556, furnished under other contracts, and the cost of superintendence and inspection, amounting to $2 264.

The cost of the second step, not including the abutments or the rip-rap apron below the dam, is $37 575, or $30.06 per lin. ft.

The rip-rap protection below the apron, placed during 1905, consists of 5 472 tons of large rock, costing in all $13 604, or $11.83 per lin. ft.

The cost of the entire work of construction of the first two steps, but not including the end abutments, has been $129 792, or $103.83 per lin. ft.

*Daguerre Point Section.*—The plans for the treatment of the intermediate section of the Yuba River involve the construction of high embankments of river gravel extending entirely across the



FIG. 1.—PILING COMPLETED FOR SECOND STEP OF BARRIER.



FIG. 2.—SECOND STEP OF BARRIER NEARLY COMPLETED.

U of W

river in a V-shape, with the apex up stream, the down-stream ends connecting, one with Daguerre Point on the north, and the other with a high knoll on the south bank. These barriers are to be so high that they will never be over-topped.

A diverting barrier connects the apex of the V with the north shore, diverting to the south all water below the elevation of its crest. Through Daguerre Point is being cut a channel, 600 ft. wide and 25 ft. deep, through which will pass all the river flow at high stages.

On the south bank, regulating works will admit all the water turned by the diverting barrier, up to a limit of about 3 000 cu. ft. per sec., passing it into a natural depression of about 2 sq. miles area, adjoining the river on the south. These works will exclude all flow greater than what is considered safe, compelling the excess to pass to the north over the diverting barrier and through the cut. This plan is simply taking advantage of the natural regimen of the river.

All rivers have their sections of active erosion, usually where slopes and velocities are highest; their sections of transportation, where slopes and velocities are sufficient to carry sediment, but not to scour; sections of sedimentation, where the reduced velocities permit the sediment to fall and form deposits, and their sections of discharge.

The construction of the embankments and the use of a large settling basin only increase the natural area of the section of sedimentation. The river is passed into an area where the velocities are largely checked, although not entirely overcome, so that practically all their load of sediment is dropped. The water passing back into the river at the lower end of the basin will be practically clear. At stages of the river, occurring for a short time only during each year, when the flow of water through the settling basin would be more than 3 000 cu. ft. per sec. and more than could be settled, the regulating devices will exclude the excess, causing it to pass into the cut. As the river is below this limit for by far the greater part of the year, this will happen only at intervals, and then at such high stages that the velocities are thought to be sufficient to carry whatever fine sediment is in suspension into the Feather and Sacramento Rivers, which, being at flood at the same time, will

carry the sediment into the tidal currents of the bay and thence into the ocean. As the periods of such high water are short, the damage to the navigable rivers, if any should result, will be limited, and will in any case be less than the river can repair with its own scouring action.

The work of excavating the cut at Daguerre Point has been in progress for more than two years. About 650 000 cu. yd. of excavation have already been removed, and the work is now nearing completion.

A steam shovel having a 1½-cu. yd. dipper is used, the excavated material being removed, by two trains of about 10 cars each, to the dump at the north side of the entrance. An average of 30 000 cu. yd. per month is required under the contract, which will be completed by the close of the calendar year. The contract price of excavation is 23½ cents per cu. yd. of earth and 90 cents per cu. yd. of rock removed. The total cost of this cut will be somewhat more than $160 000.

*Lip.*—In order to prevent unusual scour through this cut, which must take nearly all the maximum flow of the Yuba River, amounting in floods to as much as 90 000 cu. ft. per sec., and perhaps more, it was necessary to construct an inlet wall or sill at the entrance. This is of masonry, and is sufficient to hold the bottom and banks in its vicinity during this extreme flow. Accordingly, contracts have been let for a reinforced concrete sill with a reinforced concrete abutment at the north end and with a rock face for an abutment at the south end. This work is now under construction. The length will be about 700 ft.

The estimated cost of the work is given in Table 3, the prices being those of the contracts now in force:

TABLE 3.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Excavation ..... | 2 200 | cu. yd. | earth, | at | $1.00 | per yd. | $2 200 |
| " ..... | 200 | " | rock, | " | 1.50 | " | 300 |
| Back-fill..... | 140 | " | | " | 1.00 | " | 140 |
| Embankment..... | 300 | " | | " | 0.75 | " | 225 |
| Concrete..... | 2 340 | " | | " | 5.00 | " | 11 700 |
| Plain steel bars..... | 30 100 | lb. | | " | 0.06 | per lb. | 1 806 |
| Twisted steel bars .... | 8 300 | " | | " | 0.07 | " | 581 |
| Excavation at entrance. | 32 000 | cu. yd. | earth, | " | 0.45 | per yd. | 14 400 |
| | 1 000 | " | rock, | " | 0.45 | " | 450 |
| Total ..... | | | | | | | $31 802 |



FIG. 1.—TOP VIEW OF BARRIER; SECOND STEP NEARLY COMPLETED; RIVER PASSING AROUND FARTHER END.



FIG. 2.—SECOND STEP OF BARRIER COMPLETED. DEBRIS ON STEPS WILL BE REMOVED BY FIRST HIGH WATER.

Cement is furnished by the Commission, and costs $2.25 per bbl. in Marysville and 41 cents per bbl. for hauling 11 miles to the site of the work.

The average cost, excluding abutments and the excavation of material in the entrance, will be approximately $35.40 per lin. ft. of length of the wall.

It was originally intended that the United States should build the high embankments extending across this part of the river, but before operations could be begun it was found that a gold dredging company had secured extensive mining rights in the vicinity, and that this promised to conflict decidedly with the plans of the Government. It was also learned that the company, in the exercise of its rights, proposed to dredge for gold in the river-bed just where the original settling basin had been located. After considerable controversy, an amicable agreement was reached by which the Commission was enabled to obtain a larger settling basin on the south side of the river in exchange for the location first adopted, certain deeds to property essential to the project were secured, and the dredging company also agreed to build the necessary embankments free of cost to the United States. The area mined was to be returned to the United States when it had been completely dredged, for such use as could be made of it. The embankments were of considerable value to the dredging company, as they protect its operations during high water, but they are built along lines proposed by the United States and save the cost of construction to the United States. The total length of embankment will be about 2½ miles. About ½ mile has been built already with only two dredges. Six more dredges are under construction, and will be placed on this embankment work as soon as completed. The embankments now being built are about 30 ft. high and from 200 to 300 ft. wide on the base. They will not be over-topped. These embankments will be completed, it is expected, by the close of 1906.

*Training Walls.*—Below Daguerre Point the debris in the river-bed is from 7 to 25 ft. deep, increasing from Marysville as one proceeds up stream, and forming a body about 2 miles wide, on an average, and more than 9 miles long. The project contemplates confining the river to a selected channel and leaving the remainder of the old bed undisturbed. Portions of the old bed may be used for

settling basins, but the unrestricted movement of the river over this abnormal width of bed is to be prevented. This will be effected by dikes at proper distances apart, which will contain the maximum flow. This will undoubtedly result in some scour in the selected channel until the equilibrium of the forces at work has been more nearly reached. This action, however, will all be in the direction of greater security from floods. Already, agreements have been made with two gold dredging companies to build 2 miles of these walls, lying on the south side of the channel below Daguerre Point, free of cost to the United States. The north wall for a corresponding length of 2 miles is now being built under contract by the Commission at a cost of 12.4 cents per cu. yd. of material in place. The total quantity in this north wall will be about 200 000 cu. yd. The distance between these training walls at the upper end is 2 000 ft. The distance apart will be adapted to the slope and the height of the walls in the lower reaches.

*Other Rivers.*—During the summer of 1905 a survey party was kept in the field surveying Bear River, with a view to its treatment along similar lines. The Bear has been surveyed from its mouth in the Feather up to the mouth of Greenhorn Creek, a distance of 32 miles, sites for dams have been examined, and a plan for work is now being formulated.

The American River will next be studied, and a plan for its treatment prepared.

When these other rivers have been remedied, the worst offenders will be rendered harmless, and the Commission can then turn its attention to the other problems of navigation and flood control in the Sacramento Valley.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## A NEW GRAVING DOCK AT NAGASAKI, JAPAN.

### Discussion.*

By Charles Albertson, M. Am. Soc. C. E.

Mr. Albertson.

Charles Albertson, M. Am. Soc. C. E. (by letter).—The original graving dock in Japan was not a graving dock at all, in the present sense of the word. It was simply a sheltered cove or a sandy beach protected by nearby headlands from the severe winds and typhoons which occur at certain seasons. These beaches are found all along the coast lines of the four main, and the many lesser, islands which compose the Island Kingdom. Even to this day, the largest junks are beached in the old-time way, in order to clean the hulls and make minor repairs during the successive periods between high tides.

For centuries the Japanese had been experienced in the control of water for purposes of irrigation, therefore it is quite probable that the next step in their docking operations was to build a small dam and gate, sufficient at least to protect the little inlets from the peak of the high tide.

From such small beginnings to the great graving dock described by Dr. Shiraishi is a tremendous leap, but the Japanese have shown themselves capable of doing just such things.

One would scarcely dare maintain that the necessity for such docks or the ability to design and build them could have come about except for contact with the nations of Europe and America. Their docks are based on the best foreign practice, but are slightly modified

* Continued from January, 1906, *Proceedings*. See October, 1905, *Proceedings* for paper on this subject by Naoji Shiraishi, M. Am. Soc. C. E.

Mr. Albertson. to suit the local demands and conditions. Nevertheless, it is no small matter to build a good dock in Japan, owing to the inexperienced, careless, heedless labor which must be used on such works. The laborer does his work in a very mechanical manner, and all his thinking must be done for him. It is a pleasure to know that Dr. Shiraishi has been entirely successful in the construction of his dock.

Japan is fortunate in having an indented, rather rocky, sloping shore line, which is naturally adapted to dock construction. The Japanese have made good use of these conditions, and most of their dozen or more large private docks are built directly on a rock foundation. They are all faced with native granite. The pump-houses are largely below ground, and contain electrically-driven, direct-connected, centrifugal pumping outfits. Dr. Shiraishi's article describes Japan's present standard practice.

Mr. Jacobs, in discussing the paper, stated that another gate in the middle of the dock would have been an improvement on the design, as one or two small vessels could have then been docked separately. While this might be true, ordinarily, if other docks in the immediate vicinity were not available, and but few large vessels were to be docked, it does not hold in the case of the Nagasaki dock. The owners, The Mitsu Bishi Company, have in operation two other docks and one patent marine railway. The dimensions of these smaller docks are: length on keel-blocks, 510 and 350 ft.; bottom entrance width, 77 and 53 ft.; and depth of water on keel-blocks, 26½ and 24 ft., respectively. The marine railway can accommodate a vessel of 1 000 tons. These, with the other small shipyards in the neighborhood, fully cover the docking requirements of Nagasaki's beautiful harbor.

In regard to cement, the writer shares the opinion which is general among foreigners in Japan, that the best Japanese cement is not equal to the best imported article. Some evidence of this is given by the Japanese themselves, in that the new dry dock, of the Kawasaki Dock Yard Company, Limited, at Kobe, was built with imported cement. This dock cost more than the big Nagasaki dock, although it is not nearly as large, since it measures 426 ft. from caisson to head wall toe, bottom entrance width 52 ft., and depth of sill 24 ft. The great cost was due to the company's shipbuilding plant having been located on bad ground, without considering dry-dock requirements. This necessitated piling and a large quantity of concrete. The Mitsu Bishi Company profited by the experience of the Kawasaki Company, and have now in use in Kobe Harbor a steel floating dock of 7 000 tons capacity.

Before giving up his residence in Japan, the writer saw the early stages of the construction of the Nagasaki dock. He is of the belief that, under the conditions existing then and there, only a little

more machinery could have been used either to advance the work or decrease the cost. The thought is that perhaps an addition to the limited hauling equipment, or even a further installation of some very simple type of conveying apparatus might have been desirable. This, probably, would not have decreased the cost to the contractor, although it should have reduced by a little the time taken in construction; but, then, time is not considered as valuable in Japan as it is in America. Mr. Albertson.

The writer feels that the credit for the design as well as the construction of this the greatest dock in the Far East properly belongs to Dr. Shiraishi, although he modestly refrains from giving even a clue as to his continued connection with the project.

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# PAPERS AND DISCUSSIONS.

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## THE POSITION OF THE CONSTRUCTING ENGINEER, AND HIS DUTIES IN RELATION TO INSPECTION AND THE ENFORCEMENT OF CONTRACTS.

### Discussion.*

BY MESSRS. JAMES SMITH HARING, W. D. LOVELL, BENJAMIN THOMPSON, S. BENT RUSSELL, WILLARD BEAHAN, W. A. AIKEN, AUGUSTUS SMITH AND G. S. BIXBY.

Mr. Haring.

JAMES SMITH HARING, M. Am. Soc. C. E. (by letter).—The author seems to lay particular stress upon the "tact" which an inspector on construction should possess. The writer agrees with him, but would emphasize equally the fact that an inspector must be, also, thoroughly honest and thoroughly loyal to his chief or his principal. The writer has been a sufferer in cases where an exceptional amount of "tact" in his inspectors and an absence of honesty and loyalty have not only suffered the work to be compromised, but his own position to be jeopardized—the "tact" working for the interest of the contractors.

The personal equation of contractors is as material to courteous relations on work as the personality of the inspector. Some contractors are honest in their intentions and faithful in the perform-

* This discussion (of the paper by Albert J. Himes, M. Am. Soc. C. E., printed in *Proceedings* for November, 1905), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.
Communications on this subject received prior to March 30th, 1906, will be published subsequently.

ance of their obligations, no dereliction of duty or performance is a part of their creed, and yet they may have in their employ men actually performing the work who think they can perform or omit the performance of certain obligations in a manner that will save money for their employer, thereby advancing their own prospects. Necessarily, a careful inspector objects to such actions, and, unless the contractor is himself honest enough to see the justness of criticism, friction must arise, and the result soon determines the relations between the engineer and the contractor. Mr. Haring.

Chief engineers, themselves, are not always reasonable in their relations to either their inspectors or the contractor. The writer had occasion to observe this not long ago. Through a series of misfortunes, a contractor was doing a piece of work at a considerable loss, financially, but, notwithstanding this fact, when any reasonable request was made by the inspector for any particular item to be executed, it was done with alacrity and cheerfulness, the whole aim of the contractor and all his men being apparent in an attempt on their part to do the best work possible regardless of the cost. With all this evidence of good intention before him, the chief engineer, in several instances, cast suspicion on the work, both of the contractor and the inspector, in a manner so aggravating (and affecting matters so trifling) as to arouse the antagonism of the inspector, who was both honest and loyal, and the contractor, simply because it was unjust; yet the work, when completed, received the most positive commendation as being first-class in every particular, and it certainly deserved such praise.

On the other hand, the writer has had certain adverse experiences with contractors. In one particular instance the contractor started out with the avowed intention of laying all manner of pitfalls for the engineer and his inspectors, intending to catch them sufficiently at fault to find cause for making the contract void and laying the blame on the principals, behind the engineer, who acted upon his advice. In two other cases the incompetency (inexperience or financial inability) of the contractors was shown at the very beginning of the work, and it required not only "tact," firmness, and a knowledge of contract law, but a fight against political influence in the camp of his principals to enable the engineer to guide, not only the details of the work, but the persons who were paying for the work, out of grievous and sore tribulations, and to save his own reputation.

Too much cannot be said regarding the knowledge of the law of contracts to be possessed by the engineer. He must be able to protect his own rights, and unless acting for some corporation which maintains a legal department or retains regular counsel, he should be able to advise and direct those for whom he acts. In any condi-

Mr. Haring. tion, the engineer is charged with large responsibility; he is the active agency to take the responsibility for the work of his inspectors and assume it as his own; he is the target of the contractor and all his employees, and must stand their criticism and too often their abuse; he must frequently meet a combination of the contractor and his own employer or principal trying to place him in the wrong; so that his justification and defense must stand on indisputable grounds of right, or he is likely to fail utterly.

The condition which makes the engineer sick at heart, however, is to find honest effort on his part met by censure and condemnation in the light of the most positive evidence of the fact that his course is correct. The writer recalls a condition where he, as engineer, called to his aid inspectors whose capabilities, honesty and loyalty had been proven on other work. These inspectors did their duty against adverse circumstances. The work was for a municipality, and he regrets to say that he has spent whole sessions with the governing officials, who took up the time, badly needed for important business, in listening to the complaints of inexperienced contractors against these inspectors, simply because they had performed their duty conscientiously. The writer upheld them, and refused to countenance censure or removal. Finally, he himself was replaced by a more pliable man, who permitted the contractors to obtain payments for extra work to which they were not entitled, and who permitted the use of materials the writer had rejected.

In another instance the writer was engineer on a contract abandoned by the contractor because the engineer ordered an additional quantity of work done at a specific price named in the contract. The work was finished by the municipality under the terms of the contract, the writer acting as engineer, and a large deficiency for cost of construction has just been obtained by a jury trial in a suit to recover from the contractor.

Under any conditions, the engineer and his inspectors occupy responsible positions. If due consideration is not given in the selection of the inspectors, and there is not sufficient latitude, or absolute control of appointment, it too frequently occurs that competency is not the determining factor in the choice of men. A contractor is very soon able to "size up" the capabilities of the man who is to watch his work, and he acts accordingly.

As this is the age wherein women seem to be displacing men, the writer has often wondered whether the time will come when, to some degree, women will displace men in the engineering profession. In certain cases mentioned herein the proverbial "tact" of women might be found to be advantageous.

Mr. Lovell. W. D. LOVELL, M. AM. SOC. C. E. (by letter).—This topic is one of general interest to both engineers and contractors. Undoubtedly,

"there is too much laxity in the preparation of specifications." It has become the custom with many engineers to write their specifications hurriedly, or to have them prepared by an incompetent assistant, and then, to make sure that they have covered everything, to put in a general clause, as pointed out by the author. This blanket clause is an admission of the weakness of the specification, and its use should be discouraged. In making up his bid, the contractor depends upon the written specification to describe the work he is expected to perform and not upon the "general conditions" which may mean nothing, or a great deal, depending on the inspector. Mr. Lovell.

In one instance, coming to the writer's notice, the specification relating to concrete seemed to be voluminous. Omitting the specification on cement, one thousand words were used in describing concrete, yet, when construction began, the inspector found it necessary, in order to get such work as he thought desirable, to hide behind a general clause, applicable to all divisions of the work, which stated that "all work must be done in a workmanlike manner." Relying on this blanket clause forced the contractor to increase the actual cost of the work 50%, and no extras were allowed. It is injustice like this which causes unpleasant relations between inspector and contractor, and brings the engineering profession into disrepute.

It often happens, especially on Government work, that the man who writes the specification has no part in the supervision of the work. The opinion of what is a "workmanlike manner," on the part of the man who wrote the specification, may differ widely from the ideas of the constructing engineer. The man who wrote may have had in mind a good class of commercial work with nothing fancy or finished about it. The inspector may happen to have decided opinions regarding the finishing of work, and may attempt to compel the contractor to do the work according to his ideas. He cannot do so by the specification on that particular subject, therefore it is necessary for him to call up the "general conditions," usually written in specifications, that "work must be done in a workmanlike manner" or "to the satisfaction of the engineer." This is not a fair interpretation of the specification or the contract, and yet, as is suggested by the author, a contractor very often submits to just such injustice because he cannot afford the time or the money to take the matter into court. Each specification, covering any one part of the work, should be written so that it should not be necessary for the inspector to rely on general clauses to support his requirements in regard to the character of the work, and "blanket clauses," which may be used as a gross injustice to the contractor, should be omitted, except to cover unforeseen contingencies.

Mr. Himes has mentioned the necessity of the inspector knowing his business, and being familiar with the conditions surrounding the

Mr. Lovell. contract. The successful inspector must have a practical knowledge of first-class work. The contractor often repeats the old saying, "I have no trouble with the inspector who knows his business." It is the man who is afraid of his own position—who does not really know whether he is right or wrong—who, by his unreasonable requirements on some points and his laxity on others, shows his lack of knowledge, loses the respect of his chief and the contractor, and proves a failure as a constructing engineer.

The following is a case in point: The work consisted in laying cast-iron water pipe. The inspector was diligent in chipping and tapping the castings, although he had a certified test of the material used in the pipe and a sworn statement that each length had been tested under a pressure of 300 lb. He was careful to see that the letters, indicating the manufacturer and the year in which the pipe was cast, were easily legible, and that the dust was wiped out of the pipe before it was laid; yet, when it came to the really important work of seeing that the pipe had a good uniform bearing in the trench, that the jute was driven back, and the lead joint deep, properly run, and thoroughly caulked, he paid no attention whatever.

A part of the line was through a corn field, where any settlement of the back-filling would make no difference, as the field would be plowed over in the following spring. The back-filling was to be done with a scraper, the earth wet down with water furnished by the city, and pumped at considerable expense from a deep well. The inspection of this back-filling was the most severe that could be imagined. The additional cost to the municipality, on account of pumping water alone, was considerably more than the salary of a qualified inspector.

Mr. Thompson. BENJAMIN THOMPSON, M. AM. SOC. C. E. (by letter).—Mr. Himes' paper treats of a very important subject, and the writer, without desiring to be critical, wishes to state that it is not so much fluency of diction that is needed in writing specifications as plain, definite, specific, concise, comprehensive statements. It sometimes happens that specifications are what might be called a literary effort, which is apt to confuse and bemuddle the contractor, who, more often than not, has had no more education than what is embraced in the "three R's." What he needs is plain writing, showing clearly and specifically what he is to do, when he is to do it, and what and how he is to be paid for it. If the engineer has not investigated the situation and the conditions surrounding the proposed work in detail, he cannot prepare fully what the contractor ought to have for his guidance. The more care in preliminaries the less difficulty with contractors, and the less embarrassment in explaining why the total cost exceeds the estimates, the latter being the standing indictment against civil engineers.

Mr. Thompson.

The author's epigrammatic statement that "confinement on suspicion is fully as inconvenient as confinement on conviction," "should be indelibly engraved in the memory of every young engineer," as Mr. Wellington would have said. And the writer would like to add Whittier's "Ah, what a thin partition shuts out from the eyes of the curious world the knowledge of evil deeds done in darkness."

The author's question, "Has any one heard of a multi-millionaire engineer?" reminds the writer of what was said to him some time ago by a gentleman who had just paid $40 000 commission to a real estate agent for the sale of some property. "That man worked two or three months, and an engineer might work as many years or more to get the same amount."

The writer asked, "Why should the real estate agent receive so much higher pay for his services than the engineer for an equal or much larger amount of work to make the sale possible?" His reply was, "I don't know, unless it was because he got the money."

Inspectors or resident engineers on extensive work usually come from different sections of the country, and have different ideas as to good construction, and how to proceed in special difficulties. It seems to the writer that it would be a good plan for the chief engineer to have the engineers and inspectors come together at the beginning of the work and at various times during its progress for the examination and discussion of the specifications and their application to the special difficulties or problems which may be met. If this were done, the character of the work under their charge would be more uniformly good, contractors would feel that they were all treated about alike, the individual inspector or resident engineer would feel that he could take a position in which he would be sustained by the judgment of his comrades and his chief, with the least annoyance and trouble to the latter, and the chief engineer would be doing most valuable service, not only to his employers, but to those under him.

Mr. Russell.

S. Bent Russell, M. Am. Soc. C. E. (by letter).—This subject covers much of the whole field of engineering, and so much may be said upon it that it is not easy to treat it well within the limits of a brief essay.

The broad question of the proper interpretation of engineering specifications is of such importance to engineers that it might well be classed with those subjects that should be brought up annually for discussion.

Consistency is of great importance, both in writing the specifications and in executing them. Not only should an engineer be consistent in his own practice, but neighboring engineers should advise with each other, and try to make their practice consistent.

Mr. Russell. Going a step further, there should be a certain amount of consistency aimed at among the members of the whole profession.

The dictum of the engineer should gain strength, and, indeed, often does gain strength, by the fact that it not only represents the judgment of a man especially trained for the work, but also in a measure represents the consensus of opinion of the whole engineering profession.

The standing of the profession will certainly be elevated by greater unity among engineers in the matter of engineering contracts. A great deal of missionary work is needed among engineers. They should be better informed as to what is the best practice, both in writing and in interpreting specifications.

The author is to be congratulated upon his successful opening of so important a discussion, and upon the many good points that he has brought up in the paper.

As to preparing specifications, engineering has now become such an advanced science, and the volume of engineering knowledge has become so vast, compared with the capacity of any individual, that, with little violence, it might be said that when an engineer starts to write a specification, he is working on a subject of which he has little or no personal knowledge. For example, he may have had much experience in building structures of steel and of masonry, and now be called upon in the line of the structure of timber. He is dependent upon the work of other engineers. His information must be gathered from books, periodicals, etc.

Perhaps the first question for the engineer to decide is how much time can be given to research work. It depends, of course, upon the importance of the case. Most errors in engineering specifications come from lack of time and information in preparing them.

In the writer's judgment, engineers more often give too little time than too much to specification writing. Many a lawsuit could have been avoided by a few minutes more time in the beginning. This is a point that could be thoroughly discussed by engineers with great advantage, and the position of the author is well taken as to better specifications being needed.

Perhaps the next question, with the engineer who starts to draw up specifications, is the state of the market. If contractors are known to be hungry for work, specifications, of course, may be severe. They may be written so that the contractor will be lucky if he gets his capital back.

On the other hand, if contractors are well supplied with work, they are usually very independent. The engineer must see that the specifications are more than fair to the contractor. Otherwise, he will get no bids, or excessive prices.

Coming now to the inspection of engineering work, as in the

drafting of specifications, it is found that the greatest difficulties come from ignorance. Young inspectors, of course, do not know what is customary practice in the line of work which they are called upon to judge. In their inspection, they are often at a great disadvantage, in that they know less about what is right and customary than the contractor himself, and yet they must expound the law and control his actions. Mr. Russell.

On the other hand, inspectors of more experience are often worse, on the whole, because they have been badly trained. An inspector who has served under a careless or incompetent engineer may be very unsatisfactory, owing to faults in his training. An old bricklayer does not always make the best inspector of brickwork. He is apt to be prejudiced by the kind of work he has been doing in his trade.

The number of inspectors or the quantity of work to be covered by one inspector is a matter of great import. One does not like to have the cost of inspection too high in proportion.

Engineers, as a class, should insist that the success of the work should never be imperiled by fear of criticism as to the cost of inspection.

At the outset the inspecting engineer may well bear in mind the state of the market when the contract was let, as mentioned previously, and thus infer the probable width of margin on which the contractor has to work. The keener the competition the sharper should be the inspection, as a rule. More often than not, the amount expended on inspection is below the point of greatest economic results.

Specifications which give arbitrary power to the engineer are too apt to put him in an improper state of mind. With the best intentions in the world, an engineer unconsciously becomes careless of the rights of the contractor and sub-contractors until he is confronted with a lawsuit. The engineer and inspector should guard carefully against this failing.

Perhaps the most important point mentioned by the author is "the practice of helping out the contractor." In the writer's judgment, the views of engineers on this point should be fully brought out, and a great effort be made to get the consensus of opinion of experienced engineers on the question. There is too much variation in the practice of engineers in this direction. Personally, the writer thinks that, in any work of a public nature, the engineer should never permit "helping out" the contractor. Obviously, it does no good to contractors as a class, and better results will be obtained with the practice ruled out altogether.

In private contracts, this practice should never be allowed, without full knowledge of all the parties interested.

Mr. Russell. It should be noted here that there is often a third party, not named in the contract, but interested in the result, financially or otherwise, and this party is depending upon the fairness and integrity of the engineer to protect his rights and see that the work is executed as planned and brought to a successful conclusion.

The engineer should keep the interests of the third party in mind, and guard them where it is proper he should, or advise such party of any proposed changes in the work.

A matter of similar bearing is the proper treatment of subcontractors. The engineer should be fully informed as to the status of such parties, and should know whether they are being fairly treated by the general contractor; and, where their interests are at stake, should keep them in mind, carefully avoiding just cause for complaint from them.

An error that the engineer should guard against especially is that of allowing the contractor to deceive himself by practicing a sort of confidence game upon him. The contractor is allowed to believe that he is to be "helped out" by the engineer at some later time, and thus he is kept in good humor and tractable, without the engineer really committing himself. This is sometimes the engineer's method of managing the contractor, but it is decidedly dangerous, and should not be followed.

Engineers should settle disputes as soon as possible, and should not defer them. There is room for a great deal of diplomacy in the management of contractors who are engaged upon different parts of the same work, so that each shall be made to think that he is being treated at least as well as any other contractor. To do this, under all the complications that come up in engineering work, is sometimes most difficult.

At times, where a contractor shows a disposition to make trouble, the engineer will make concessions to him that are of doubtful propriety, in order that, should a lawsuit come up later, he may show that the contractor has been treated liberally. This, of course, is treading on dangerous ground, and the engineer should be very careful not to go too far in this direction, as his motives may easily be misconstrued.

The question of covering up errors made by the engineer in writing specifications, or in the plans or instructions, is one that could be discussed with interest. How far may the engineer go with propriety in this direction? This question often arises in actual work, and is frequently of great import. It is doubtful, however, if any generalizations can be made for such cases that would not apply to the conduct of human life.

The writer hopes that the points thus briefly called to mind will add something to the interest of the discussion.

Mr. Beahan.

WILLARD BEAHAN, M. AM. SOC. C. E. (by letter).—This paper is an unusual one in both its field and scope, and will be useful to the profession. Engineering has been broadening much of late, and annexing new territory to the old province of mathematics and science. This paper is of the new learning upon which engineers are entering. It trenches much on law, and it has to do with human nature. In each direction an engineer always needs instruction, and to-day more than ever.

The author states that "A contract is a meeting of minds," and that there must be a "clear and definite understanding of what is to be done." Now, this understanding of the two minds is the contract. The written instrument is but a reflection of it, and is sometimes clouded by legal phrase or ignorance of the niceties of technical terms. That printed blank which we fill out is not the contract, in the eyes of the law. This fact makes blanket clauses a confession that the minds have not clearly met, and hence the contract is faulty, and the door of misunderstanding and of litigation is confusedly thrown open.

Engineers differ as to whether a detailed contract and specifications which endeavors to cover all points fully and minutely is best; or whether a brief and general specification is best. The writer supposes that each engineer will ever favor that one of these two which is better in accord with his own temperament. Governments and municipalities favor the first kind, while corporations and firms very often favor the latter. Most engineers will agree that, in general, during the execution of work under contract, questions will arise which are at least on the border line of the terms of the contract, and will raise questions for adjustment. The engineer in charge is the one to whom these questions present themselves, and they are a crucial trial to him. With reference to these recurring questions the writer's instructions at the outset of his career, as given to him by the late D. W. Washburn, Chief Engineer of Construction on Mr. Gould's South-West System, were as follows: "You are, of course, employed and paid by the Company, but it is your duty to stand between the Company and the contractor, and say what is right in equity." Thirty years have almost passed, but to the writer the instructions still seem to be right. Common sense is good railroading, and honesty is the best policy, as well as the best politics. No contract can be drawn that makes the exercise of judgment unnecessary.

As engineers, we cannot compel a contractor to do work not really shown on the plans or in the specifications or in the contract. Some contractors have done harm to engineers by willingly doing such work just to cover some sins of omission. The whole is vicious. If a mistake is made and some work is left out, say so;

Mr. Beahan. it is better for all, and cheaper for the company, to handle this as extra work outside the contract. The engineer or inspector who accepts favors from the contractor is lost. Blanket clauses are put in contracts to cover just such careless work, but anyone at all familiar with the law of contracts knows very well that such attempts are futile, and this fact is clearly brought out in the paper. It is to be hoped that the quoted clause in the elevator and power-plant contract is the very limit of unwisdom in this direction.

"Absolutism has no place in business." One would think this were not true if he read some contracts, where it would seem that the engineer can do anything he pleases and pass any judgment he sees fit. But the Courts sometimes make short shrift of such contracts, and it is readily seen that a "meeting of minds" has not yet convened. In fact, a "printed form," when used in a contract, biases a jury and brands that contract as arbitrary. As a profession, we need to know how Courts and juries view us and our acts. We need to get out of our offices and drafting rooms and just "come down to earth" and mix with the multitude. By doing so we can better earn our salaries in our mature years.

It is indeed hard to say what is 89% and what is 91% when 90% is the mark at which inspections are passed. As inspectors, in our younger years will we not mark it 89% and in our later life mark it 91 per cent.? Can we ever detect that 2% of excellence? Clearly, we must use our honest experience and judgment. But to be called back and shown that some of our 89% product is as good as some of our 91% product is the act of a young or ill-tempered contractor. An old Irishman of some experience and sound heart was once inspecting cross-ties and was shown some rejected ties on one side of the pile that were a little better than some accepted ties on the other side of that pile. After a moment's study he went back and rejected them all. Did he do right?

The absent inspection of masonry, like the absent treatment of disease, is believed in by some, but they are in the minority. There is too much inspection which does not inspect, and it brings inspection into disrepute. To have one inspector over two gangs of masons five miles apart is as foolish as to have one foreman over two gangs. This evil arises from letting too many small contracts when the cost of inspection thereupon adds much to the unit cost. A better plan is to do these small jobs by a company force.

The case of the mill inspection of rails cited in the paper raises this question, naturally: May it not cost less to try to make first-rate rails than it will cost to make poorer ones and take the chances of their rejection? Some may have seen grading contractors haul logs and brush into an embankment when it would have cost less to burn the logs and brush and haul in earth instead. Cheating comes

to be a chronic disease at the last. The writer once knew a contractor to tell a falsehood wilfully when it was against his interests. His brother, who was the other member of the firm, said, "W. is a fool! W. will lie at sixty cents on the dollar when the truth would be worth par." We can form the habit of thinking that the truth is ever against us. Mr. Beahan.

An inspector, not sustained or "backed up" by his superior, is a man whose salary is money wasted through no fault of his. Honesty, capacity, and courage are essentials in inspectors, or in engineers in immediate charge of the work. Said a prominent chief engineer of a granger road to the writer a few years ago, "I have had two hundred and forty civil engineers of various grades on our work this summer and in not a single case has there been the least suspicion of dishonesty." In a quarter of a century of railroad work over much of the United States the writer has never seen a dishonest act by an engineer. He has had only one dishonest engineering employee—a paymaster, and under mitigating circumstances in a foreign country. Will our friends, the contractors, who are given to careless expression, please commit to memory these statements of the writer on this point? Capacity, however, is a rarer quality. The writer thinks that too much is expected of young engineers as inspectors. It is not fair to them. The writer fully agrees with the paper, but must say that, for an inspector of execution, rather than of manufactures, he prefers an experienced craftsman. For example, his best results in pile-driving have been in using an experienced pile-driver man as an inspector, rather than a young engineer. So, too, for a modern building, he prefers a first-class carpenter who can read a plan, rather than a young architect or engineer. For such work he prefers an old foreman, of unusual intelligence, who, perhaps, may be in poor health or crippled, but who possesses all his faculties. If he has been for a long time with the company, so much the better.

Courage is a quality of character, rather than of education or experience. Years ago a collegian was not thought to be courageous, but college athletics have changed all that. Moral rather than physical courage is the kind most required, but they go best together in this case. Bluster is the outward expression of pure cowardice. The brave are quiet and use few words. Of these three great qualities it may be said that, as a rule, honesty is a matter of course with a technical graduate; capacity can be trained into him, while courage he must have inherited, in the main.

The author has properly pointed out the fact that tact is an essential to greatness in the engineering profession. Tact is not taught in technical schools nor could it be. But a little tact might have been talked to us now and then to good advantage. We were

Mr. Beahan. taught intolerance, and were sometimes taught self-sufficiency. This is not seen in the later generations of students, however. In later years engineers must learn that tact which they ignored at first. Tact is ready money where talent is capital. As a profession we are at fault in not cultivating tactfulness. It is the new learning of our calling and the younger engineers should take up the study of it right away. Knowing a thing is not enough. One must also be able to make others and capital know it, too, and through one's own self as the instrumentality. Learn a thing, learn to tell it or write it, learn to do this convincingly, and, finally, learn to do so in a pleasing way.

Mr. Aiken. W. A. AIKEN, M. AM. SOC. C. E.—It is very refreshing to find in this paper a clear note of appreciation of the real value of inspection; not only of the actual features of any piece of engineering construction, but particularly of the materials entering therein. It is unfortunately the fact that many engineers do not fully realize the true value of this latter and certainly equally important inspection, or, if realizing it in a general way, have neither the time nor the opportunity to acquaint themselves sufficiently with its infinite detail, and so unconsciously confound the mere matter of testing with real inspection, of which testing is only a very small part.

In the speaker's opinion, there is nothing more certain, when once thoroughly grasped by contact with a properly organized system of inspection, than that no engineer would ever think of using materials in construction unless previously they had been thoroughly inspected; for, of all the specialties of engineering technical work, no other has been so generally brought into disrepute, with those "who understand," by this age's spirit of commercialism, the dominance of which has set up everywhere the false standard of dollars and cents. Thus the cost of so-called inspection, rather than the quality of service, is unfortunately very often the conclusive argument in deciding a matter which in no way should be thus influenced. Inspection that does not inspect is absolutely worthless in itself, and is a complete waste of money. The mere matter of testing (relieving the manufacturer of responsibility, as it does in a great measure) is in many cases an absolute farce, in so far as determining the true worth of the material furnished, particularly because, as Mr. Himes states, it has unfortunately grown into a generally recognized practice that the tests submitted are to be of the manufacturer's selection.

The tonnage—in these days often involving a poorer quality of manufactured material—is another feature influencing largely the quality of inspection, unless this is carried out purely upon the basis of quality of service, instead of as a commercial enterprise. When

the manufacturing plants are crowded with orders, each being pressed for prompt delivery, and, to meet these demands, the manufacturers are putting all their efforts toward increasing their output, with the temptation to disregard its quality, an entirely different condition confronts the inspecting engineer than when orders are few and competition keen. The purchaser demanding shipment, the manufacturer, knowing that among his customers there are some whose own or commercially employed inspection is largely perfunctory, though these very customers (due to their ignorance of what inspection should consist) may not realize this, and knowing also that others are perfectly willing to accept the manufacturer's guaranty, are features of the conditions which are difficult to meet except by the strictest insistence on the specifications in all essential matters, and the exercise of clear judgment in the matter of concessions, if it is desired to obtain material complying even with admittedly fair requirements. It is under such conditions that what Mr. Himes designates as "the kicker" develops, but the speaker is satisfied that this is desirable, although, in his opinion, it is not generally necessary, and never in the case of a competent inspector, except in plants in which the methods are not "straight." Certainly, by ignoring conditions at the start, involving, as this must, the quality of inspection guaranteed (and surely, thereby, the quality of material contracted for), the inspector becomes *particeps criminis,* making it more difficult afterward to protest effectually against aggravated and intolerable conditions, and making him largely responsible for the attitude of many manufacturers toward proper supervision by the inspector.

Mr. Aiken.

Competent inspectors, even when supposedly hyper-critical, are generally so only from the manufacturer's erroneous standpoint. The manufacturers may maintain that they are entitled to only such information and facilities as are supposedly customary and called for by the average inspector. This is not tenable. On the contrary, any information in the manufacturer's possession relative to the material to be inspected belongs by right to the purchaser's representative, and may be properly called for without his deserving the name of "kicker," even though his requests may be beyond those made by the average inspector. There is no conceivable reason for a manufacturer to refuse such information and facilities, as at times is done, except the one plea that it is not customary—and this is no reason at all—or the other reason that such information and facilities would enable the inspector to keep better run of the material, and this is worse than no reason at all. A manufacturer who has nothing to conceal never objects to furnishing any information relative to material under inspection. It is only in the case of questionable practices—and, of course, these are

Mr. Aiken. not general by any means—that the "kicker" is prominently developed, and for excellent reasons. Also, occasionally, where personal feelings enter into the business relations, the manufacturer deliberately and intentionally, as it were, develops the "kicker" by continually putting obstacles in the way of his properly performing his duty, with the object of bringing him into disrepute with his superior who cannot be personally acquainted with the details of every transaction. A conservative inspector can be sorely harassed by a petty-minded representative of a manufacturer, and the patience of a Job and the tact of a Talleyrand are then necessary to steer a course where duty is fully done and no opening is given for lawful objection to method.

The specious pleas of the manufacturer to influence an inspector even properly are many, and in a measure must be recognized from the former's standpoint as possibly allowable, but these must not influence. For instance, the manufacturer may request the acceptance of a small lot of rejected material on account of its size, which from the manufacturer's standpoint determines its importance; or he may request the acceptance of a similar larger lot of material because its rejection would entail a loss to him. He may also advance the additional pleas of busy times, the uncertainty when replacement can be made, and the always prominent plea that the construction will be delayed. Such arguments, in the case of structural steel, lose their weight in some mill practices; very bad ones they are, and in time they must be controlled, when it is understood that the test pieces furnished often do not represent any considerable quantity of material actually then rolled, though they are presumably the melts from which an order is to be rolled later, if the tests pass the specification requirements.

In the case of final rejection, the loss is really nominal at the worst, the material being applied to some other order where the specifications are less rigorous or the inspection less carefully made. All of which emphasizes the fact that testing is not inspection, no matter how carefully and conscientiously the former may be done. Complete and thorough acquaintance with the process of manufacture in all stages, and the assurance that the material finally used is that tested, is the only criterion whereby to determine proper inspection, and to obtain this there is no information relative to the material that may not be properly asked for and required by the inspector.

Under all the stresses to which he is subjected, nothing is more appreciated by him, nothing is more necessary to him, than the endorsement of his superior officer; and nothing, even from the most selfish standpoint, pays the engineer so well in securing the best service from competent men as the proper support of his inspectors.

Mr. Aiken. While concessions may be properly made at times, in the judgment of a competent inspector or under general rulings of his chief, the idea that a reason must be found for the acceptance of material, whenever it fails to meet certain specifications, is too often the attitude of the manufacturer. The inspector in charge, knowing as he should, the use to which any material is to be put, must be the judge. Any other viewpoint is subversive and not to be tolerated.

It is to be hoped that the discussion of this most important class of work will cause engineers to recognize more clearly the value of proper inspection, which is undoubtedly of benefit to the manufacturer, who should have common cause with the inspector in producing first-class material.

Mr. Smith. AUGUSTUS SMITH, M. AM. SOC. C. E.—This paper is considerably broader than its title would indicate. Besides the relation of the inspector or constructing engineer to his work, it opens up the whole question of that broad branch of engineering, so to speak, of how to get one's idea executed—how to get what you want done. The speaker has seen this problem from the viewpoint of the contractor—the virtuous contractor, he hopes it will be understood—and therefore will ignore the inspector altogether.

He will confine his few remarks to an idea that at first sight may appear to be irrelevant, but which has been suggested by two statements made in the paper. The first statement is on page 580* where the author says:

"The theory of the law is held by its devotees to be the discouragement of litigation, and, in this respect, because of the expense and the numerous difficulties and delays in getting a final decision, the legal profession has attained a degree of perfection which engineers may not hope to equal."

The law is so perfect in the direction pointed out by the author that, though every contract is based on ultimate recourse to the Courts, no one who has actually tried the process would think of trying again, even if he lived long enough. It is so perfect that those who practice it are making little or no effort to improve it. At the end of the last century, when, it will be remembered, a general *résumé* of progress in all lines and professions was rather a popular subject, the Law was the only profession that had no progress to report.

The second statement is found on page 589.* It reads:

"There is much said about the relations existing between the parties to a contract and the engineer, it being generally held in the profession that his attitude should be strictly impartial and that he should be no less alert to guard the interests of the contractor than those of his employer. Such a condition is a pleasing fiction, quite flattering to the engineer and agreeable to the contractor."

* *Proceedings*, Am. Soc. C. E., for November, 1905.

Mr. Smith. This is indeed a fiction. Aside from the biasing influences pointed out by the author, disputes generally arise from poor specifications, and frequently from lack of knowledge by the man who prepared the specifications who is then assumed to be impartial in interpreting them. What man, even among contractors, can be depended upon to be impartial under such circumstances?

In order to avoid the Scylla of the Court and the Charybdis of the Engineer, some contracts provide for arbitration in case of dispute. The speaker has had no personal experience with the working of the arbitration clause, but understands that in general it is unsatisfactory.

Now for a "remedy." If the American Society of Civil Engineers found it permissible and expedient to elect with the other officers a contract committee, having cognizance of such disputes as Mr. Himes refers to, much as the regatta committee of a yacht club settles all questions of fair sailing, a great advance in "arbitration" would be made.

The membership of the American Society of Civil Engineers includes many contractors and many engineers individually professional who are employed by contracting firms. A decision of the contract committee of the American Society of Civil Engineers would command more respect from this class of disputants than a decision on engineering subjects by the Court of Appeals.

Expert legal testimony might be necessary at times, but let it be the lawyer before the Bench of Engineers on purely engineering subjects, instead of the engineer before a Bench of Lawyers who are generally quite uninterested and frequently half asleep.

It would be necessary, of course, to provide a scale of fees for such a committee, properly payable by the contestants, and, if found desirable, these could be made high enough to "discourage" litigation.

Mr. Bixby. G. S. Bixby, Esq.—Mr. Himes has taken up for discussion one of the most difficult and perplexing problems in the engineering profession. To outsiders the difficult features of the engineer's work seem to lie in logarithms and angles, in those terribly long lines of figures with signs of all sorts between them and over and under them, and in the mathematical features of the work generally; but, of course, those things are mere play to the engineer, and the speaker suspects that his real troubles begin when he is held responsible for money values, and when he is made a buffer between conflicting business interests.

This paper is a very valuable contribution, from the standpoint of practical engineering. The speaker knows personally that Mr. Himes began turning these things over in his mind a good many years ago, for when the speaker first knew him he was an engineer

on the Erie Canal, and even then had the idea that an engineer was supposed to work for the interests of his employer. Doubtless he had some troubles of his own growing out of the practical application of that idea. At any rate, some other people had troubles on his account. At that time he used to spend his spare time studying law, and he must have studied to good advantage, for his points of law seem to be generally well taken. One of the most valuable suggestions made in this paper is as to keeping a diary on inspection work. As a lawyer, the speaker will say that he has never seen a witness stumped on the stand when he had on hand for reference a record of events made in chronological order. Mr. Bixby.

A prominent feature of the work of the constructing engineer is that there is a tendency in practice to exact from him what is well nigh an impossibility. Wherever engineering is made up largely of work which is soon concealed, or the evidences of which are soon destroyed, it would seem that neither the expense nor the time allowed for inspection is ordinarily enough to enable an engineer to give positively the certificates which are theoretically required from him. One cannot get away from the fact that the contractor's inerest is not that of the owner; nor that the most honest contractor when pinched on his margins will exercise a tendency to pinch on his work. One must also remember that a contractor owes a duty to himself, sometimes to his creditors, and that sometimes he is a trustee.

Another point on public work, and often on private work, is that the certificating engineer has little to do with the choice of his inspectors. In a sense they are supposed to be his agents, but often they are independent employees, and it seems to be hard to exact from an engineer a certificate in the form which, as the speaker understands it, is ordinarily required that a thing is so and so as of his own knowledge, when he cannot see everything, and is dependent on others.

As a matter of justice, an engineer responsible for results ought to have at least a partial voice in the choice of sub-engineers and inspectors.

This paper refers very intelligently to the subject of perfection in materials and workmanship. Of course, it is known that there is no such thing as perfection, and specifications ought to have incorporated in them the permitted variations more than they do. It would be simply following current practice, but, if that is so, why should it not be expressed? In public works the conditions are frequently quite inflexible. Sticks of timber and pieces of iron and steel must vary, and yet, under a standard fixed for Government work, every defective bolt may be a nail in your coffin if it comes to light.

Mr. Bixby. For instance, where hundreds or thousands of units are combined in a structure it may be unjust to require every piece to be of a standard character, and yet on public works the contract, the specifications, and often a statute unite in fixing a standard, and when there are such plain, specific provisions it is hard to invoke the doctrine of reasonableness or current practice.

There is a general opinion that a professional engineer on contract work is a kind of judicial officer, that his decision is like that of a Court, and that such decision must be made impartially between the parties. This is referred to in the paper on page 589.* The speaker does not believe that this theory has any standing in law, but thinks it arises from the fact that, as a matter of law, when, under a contract, a question is submitted to an engineer or an architect for decision, his decision cannot be an arbitrary one, but must be reasonable. In other words, the contract is to do a certain thing in a workmanlike manner, and if it is so done the inspector is bound so to decide. So, although the speaker's experience has taught him that the engineer, in practice, is very apt to be treated as an umpire, in reality he is not an umpire.

Not only is he employed and paid by one side only, but in all ordinary cases he would be subject to discharge or transfer by one side and not by the other.

This opens a very broad field for thought. The engineering profession is increasing in importance daily. The great works are multiplying so fast that we lose track of them and a hundred million dollars is becoming an ordinary sum.

The public is becoming more and more inclined to undertake these vast enterprises, and, in doing so, it is more and more dependent on the engineer. The contractors' interests also require protection. On the face, the contractor would seem to be at a disadvantage, for, while the party of the first part can ordinarily call on the engineer for such protection as may be needed, the contractor, if he disputes the reasonableness of the engineer's decision, must invoke the aid of a Court.

It is the greatest possible compliment to the engineering profession that so comparatively few lawsuits arise on important works. Of course, they arise often enough, and when they do they illustrate the difficult questions in hand.

The speaker has in mind one lawsuit now pending between a railroad and the contractor, which grew out of the holding up of final payments which would have been acceptable to the contractor at about $100 000. In the suit claim is made for $1 500 000 or more, and the contractor expects to make good his claim to many times the sum he would have accepted on the completion of the work.

* *Proceedings*, Am. Soc. C. E., for November, 1905.

Mr. Bixby.

Here is a question which often comes up: Suppose on important work a question arises which is obscure as to its solution, but nevertheless vital in the progress of the work. That is—the scope of the question is defined, it has to be decided, and engineering opinion relating thereto is divergent. Perhaps it has been in the Courts and has been decided in different ways, or perhaps it has been left undecided. What is the engineer to do, and how is he to be protected? The parties can fight it out afterward, perhaps, but it places the engineer in a very difficult position.

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# PAPERS AND DISCUSSIONS.

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## THE INSPECTION OF TREATMENT FOR THE PROTECTION OF TIMBER BY THE INJECTION OF CREOSOTE OIL.

### Discussion.*

By John B. Lindsey, Jr., Assoc. M. Am. Soc. C. E.

Mr. Lindsey.

John B. Lindsey, Assoc. M. Am. Soc. C. E. (by letter).—Mr. Stanford emphasizes the point of view that, contracts for the treatment of timber and piling being based on the weight of oil injected per cubic foot, the logical basis for inspection should be the weight injected per cubic foot. It is extremely doubtful, however, whether any system short of actually weighing the entire cylinder load of timber, both untreated and treated, would be considered favorably either by the management of the treating plants or by those who use creosoted material. The structure of different pieces of timber varies too greatly to permit the adoption of any average sample-piece method. The writer has noticed a marked difference in the treatment of different sections of the same pile, and occasionally a marked difference in the penetration on the same section. In most cases the closer grain of the less penetrated section explained the difference, but in some cases there was no apparent cause to explain the lack of uniform treatment.

The teredo-eaten pile at Pensacola, described by Mr. Stanford, with a defective 90° sector of sap wood, seems to be a practical example of the uncertainty of securing uniform treatment along

* Continued from January, 1906, *Proceedings*. See November, 1905, *Proceedings* for paper on this subject by H. R. Stanford, M. Am. Soc. C. E.

Mr. Lindsey.

the entire length of a pile where the percentage of sap wood to heart wood is much more constant at every cross-section than in the case of a sawed stick, and where conditions as to steam pressure, degree of vacuum and oil pressure were identical.

How much greater, then, does the uncertainty of uniform treatment become when the treatment of individual sticks is considered. The stick with the greater proportion of sap to heart wood, and more open grain, may receive a 20% greater injection than another stick in the same cylinder load.

Clause 4 of Mr. Stanford's proposed specifications, to insure the uniform size and structure of the pieces in each cylinder load, although entirely approved by the writer, is a difficult one to carry out fully in actual practice. This difficulty is especially great at present, as there is such an unprecedented demand for all classes of structural timber and lumber.

The percentage of the total weight to be assumed as becoming seasoned during the steaming and vacuum periods would be another vexing problem, difficult to determine equitably. The question as to whether 8% or 15% of the weight of green sticks in a load would be seasoned would mean a difference of about 4 lb. in the treatment. Such a consideration, in a plant not operated conscientiously, would have a tendency to reduce the effectiveness of the steaming and vacuum periods, affecting economy of fuel and securing a greater estimated injection of oil than actually made.

In the future the greater portion of creosoted material needed will consist of cross-ties, telegraph and telephone poles and cross-arms. Such standard-size stock will doubtless be, to a large extent, air-seasoned before treatment. Operating upon air-seasoned stock, the steaming period would be reduced to a brief interval for sterilizing the timber, or perhaps be entirely omitted. The seasoning percentage factor would then be reduced to a minimum, and with stock, say, not more than 50 ft. long it would be entirely practicable to weigh each section of the load before and after treatment. The injection could thus be determined by the estimate of the weight of oil injected in the entire cylinder load.

O. Chanute, Past-President, Am. Soc. C. E., in his valuable paper on "The Preservation of Railway Ties in Europe,"* gives the following interesting evidence of the care exercised by the German plants in treating ties:

"The most notable thing in Germany is the painstaking care with which every operation is performed. The ties are not treated until they are thoroughly seasoned, this generally takes six months to one year after cutting and piling in open piles in the yards, most of which yards will hold one year's supply. The chemicals are tested constantly, a laboratory being attached to each plant, each

* *Transactions*, Am. Soc. C. E., Vol. XLV, p. 498.

Mr. Lindsey. buggy load of 32 ties is weighed before and after treatment, to make sure that the ties have absorbed enough and every little while each individual tie of a buggy load is weighed in and out."

*Present Methods.*—The methods used to determine the quantity of creosote oil injected into timber and piling by most of the timber-treating plants in the United States are much the same, and, in all the plants of which the writer has personal knowledge, depend upon the quantity of oil taken from a supply tank, as determined by the position of a float in the tank. This float is connected to a sliding indicator on the scale board in such a way that the depth of oil in the tank is recorded in feet and tenths.

The readings of the gauge taken during the treatment of a load are usually as follows:

*A*-Reading = Depth of oil in the supply tank before any oil is admitted to the treating cylinder;

*B*-Reading = Depth of oil in the supply tank at the instant the cylinder is filled; the oil taken from the supply tank equals the content of the cylinder when empty, less the volume of the timber load;

*C*-Reading = Depth of oil in the supply tank after additional oil has been pumped into the cylinder with the pressure pump; the additional oil forced into the cylinder equals the quantity of oil which it is calculated the timber load is to receive;

*D*-Reading = Depth of oil in the supply tank when the surplus oil is returned to the supply tank from the cylinder.

The difference between Readings *B* and *C* is the estimated quantity of oil the load is to receive. Lack of accuracy in the gauge mechanism is very objectionable, and should be reduced to a minimum; however, this defect is as likely to increase as to decrease the injection.

The lack of refinement due to the use of a measuring tank of large horizontal capacity might be avoided by having a supply tank of small diameter, say, 6 ft., to measure more accurately the quantity of oil forced into the cylinder by the pressure pump after the cylinder had been filled from the large supply tank; however, with the use of two supply tanks, it becomes more difficult to secure a satisfactory check on the quantity of oil used than can be ascertained when only one tank is in service.

The losses due to leaking pipes, valves and cylinder heads are extremely small in a plant where a proper degree of attention is given to the equipment. The loss due to leaking valves is the only one not readily observable, and close inspection of the condition of the valves should be made at regular intervals.

Mr. Lindsey.

The quantity of oil absorbed by timber during the time the cylinder is filling with oil may be considerable, with well-seasoned stock, especially with such materials as paving blocks. After the *C*-Reading is recorded, and the pressure on the oil cylinder is released, preparatory to emptying the surplus oil from the cylinder, it is uncertain whether the entire quantity of oil injected into the load remains in the timber. To form a check on these probable inaccuracies, the *D*-Reading should be subtracted from the *A*-Reading, to determine the actual quantity of oil used. The difference gives the actual impregnation the entire load has received, provided there is no loss from leaking valves, pipes, or cylinder heads.

Underground supply tanks or dumping tanks are objectionable unless they are in a cellar and permit the inspection of all tank connections.

Where a plant is equipped with an elevated supply tank, the cylinder is usually filled with oil through a 10 or 12-in. pipe connection. The pipe from the tank to the pressure pump is usually from 3 to 4 in. in diameter. By returning the oil, by compressed air, after treatment, to an elevated supply tank through a 10-in. connection, the supply tank, the treating cylinder, and the connecting pipe lines could be fully examined by the inspector during the course of the treatment. With such arrangements, an intelligent inspector, after careful study of the equipment of the plant, should be able to keep a reliable check on the conscientious and intelligent operation of the treatment. This supervision would generally require day and night inspectors.

Any changes in the present methods which will place the creosoting of timber on a more precise and scientific basis, and afford the fullest possible opportunity for intelligent inspection, will be welcomed by all who have at heart the proper interests of the business.

It appears to be entirely practicable to place the inspection of air-seasoned stock less than 50 ft. in length upon a weight basis; however, in the treatment of green lumber, piling of any length, and air-seasoned material more than 50 ft. in length, the tank system of measurement, by gauging the injection of oil, will probably remain in use. Effort should be made to abandon the use of underground dumping or supply tanks, and to simplify, as far as practicable, all oil-pipe connections between these tanks and the treating cylinders. The treatment which the material is to receive may be determined by the difference between the *A* and *D*-Readings of the gauge.

*Quality of the Oil.*—The presence of water in the oil should be carefully guarded against. None of the creosoting plants have stills or the oil manufacturer's proper equipment in order to free the oil from water entirely, and they have to depend largely upon

Mr. Lindsey. the settling method. This consists in heating the mixture to, say, 180° fahr., then chilling it and allowing the water to float to the surface, where it can be discharged through a connection in the side of the tank. Steam is kept circulating almost continuously through the heating coils in the treating cylinders and the supply tank. It is of the utmost importance that these coils be tight, and that any leaks which may occur be closed promptly. The heating coils in the storage tanks, through which it is necessary to circulate steam when oil is to be drawn from the tank, should be examined from time to time, in order to avoid unnoticed leakage.

Oil received in barrels should be dumped promptly to avoid leakage. If the barrels are stored in the yard for some time considerable rain water will seep through the heads of the barrels.

The requirements that no oil with more than 8% of water be used, and that any excess of water between 2½ and 8% be compensated for by a proportionately greater injection of oil into the load, are reasonable, and should insure good work.

Specifications as to the quality of the oil are at present based largely on a distillation process. There is some difference of opinion as to whether it is advisable to allow a small percentage which will boil below 210°, or to exclude this light oil entirely. There is much difference of opinion as to whether it is desirable to have the distillate between 210 and 235° cent., 20% or 40%, or an intermediate percentage. It is certainly desirable to determine, as nearly as practicable, the most effective quality of oil necessary to preserve timber. The specification will be modified generally, however, by commercial necessities. After the coal-tar manufacturer has extracted from his tar all the higher-priced products, the residue or creosote oil is sold to the timber-treating plants. If the purchaser of creosoted lumber is informed that specifying a maximum distillate to 235° cent., of 25%, instead of 45%, will mean a 20% increase in the price of his treated timber, he is very apt to change his specification, feeling doubtful whether the increase in price is compensated for by the better quality of oil. The consulting engineer of one of the largest purchasers of creosoted timber in the United States called for bids in December, 1904, to furnish the material needed by his client during 1905, and specified that the entire distillate, up to 235° cent., must not be greater than 30%, a quality of oil similar to that proposed by Mr. Stanford. Before the date of the letting of this contract the engineer advised all bidders that he had found it necessary to revise his specification in order to avoid excessive cost to his client. The revised specification allowed a maximum distillate of 60% up to 235° cent.

When the coal-tar manufacturer finds use for a portion of the present excess of oil boiling between 200 and 235° cent., it will be

practicable, without excessive extra cost, to conform to the specification proposed by Mr. Stanford. Mr. Lindsey.

In determining the steam pressure and the length of the steaming period to be used in the treatment, the quantity of oil to be injected, as well as the size of the material, should be considered. According to the investigation of Dr. Hermann von Schrenk, of the United States Department of Forestry, the strength of creosoted material is affected, not only by the heat used during treatment, but also to some extent by the oil injected. The experiments indicated that an injection of creosote oil weakened the stick to the same extent as the impregnation of an equal quantity of water.

Mr. Stanford's observation, that heart wood is practically impervious to oil, probably applies mainly to long-leaf yellow pine piling, and particularly to the butt half of the pile, where the sap ring receives practically the entire impregnation. The writer has seen a section, from 10 to 15 ft. from the top of a long-leaf pine pile, completely saturated with oil. Where lumber is treated the impregnation in long-leaf heart pieces is generally from ½ to 1½ in. Short-leaf open-grain pine is best adapted to receive a satisfactory impregnation, and pine of this class should be secured for treatment if practicable.

The writer has an 8 by 16 in. yellow pine stringer, creosoted by Mr. J. W. Putnam at the West Pascagoula Plant in 1877, which was completely impregnated with oil at a section 3 ft. from the end of the stick. This stringer stood service in the West Pascagoula Bridge for more than 27 years. Such impregnation, in long-leaf yellow pine heart material, is unusual, however. Mr. Putnam describes the treatment of this bridge material for the New Orleans and Mobile Railroad in his letter to the Committee of this Society which, on June 24th, 1885, made a report on the preservation of timber.

It would be interesting to know if the plant, at which Mr. Stanford inspected the treatment of 80-ft. piling where such deficient treatment was secured by the tank measurement method of injection, was equipped to ascertain the actual quantity of oil used in treatment by taking the difference between the *A* and *D*-Readings.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## THE CHANGES AT THE NEW CROTON DAM.

### Discussion.*

By Messrs. William R. Hill and Frederic P. Stearns.

Mr. Hill. William R. Hill, M. Am. Soc. C. E.—The proper plan and specification for a reservoir embankment is a subject susceptible of many conflicting opinions. The formulation of such a plan depends entirely upon the condition existing at the site of each particular structure. In the main, these conditions are: the character of the natural foundation, and the character of the earth available to make the embankment. With this information at hand, the question of the necessity of a core-wall arises, and, if it is required, its character and dimensions must be determined. Then, as to the embankment itself, its height, width, slopes, paving and mode of construction must be fixed. To determine these important questions, the engineer must be guided entirely by his judgment, based upon experience and study of similar structures throughout the world. He might apply to science in vain, for he could get no help, as the efficiency of a reservoir embankment is not subject to computation; hence, it is not unreasonable to expect that conflicting opinions will arise as to the efficiency of a plan of a reservoir embankment.

Although this paper is entitled "Changes at the New Croton Dam," it treats of only one of the several changes that were made in

* This discussion (of the paper by Charles S. Gowen, M. Am. Soc. C. E., printed in *Proceedings* for December, 1905), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.
Communications on this subject received prior to March 30th, 1906, will be published subsequently.

the plan. To describe the structure briefly, it is composed of three distinct features, the spillway at the north end, the main stone dam, and the embankment with a core-wall at the south end. These, according to the original plan, had lengths of 1 000 ft., 600 ft. and 568 ft., respectively, making the total length of the structure 2 168 ft. Had the dam been built according to the original plan, the core-wall at the junction with the main stone dam would have had a height of 230 ft. Mr. Hill.

The first important change in the plan of this structure was made on September 16th, 1896, during the progress of the work. It consisted in extending the main stone dam a further distance of 110 ft., in substitution of the embankment and core-wall. That change was at once received with favor, and was carried out in the construction without any discussion whatsoever. It was of exactly the same nature and made for the same purpose as the change under consideration; that is, the main stone dam was extended in each case, with the sole object of reducing the height of the embankment and core-wall; and yet, while the first change materially increased the cost and delayed the completion of the work, it was not as effective as the change under consideration, as it resulted in reducing the height of the core-wall only 30 ft., still leaving it with the unprecedented height of 200 ft.

On January 1st, 1900, when the speaker assumed the responsibility for this work, the foundation of the stone dam had been completed to the surface of the ground, and the core-wall was completed, excepting the stretch under consideration, which lacked about 60 ft. of its height.

In the spring of 1901, the speaker's attention was called to five slight cracks in the core-wall, all within a distance of 100 ft. Relating to these, Mr. Gowen's paper states:

"It was so evident that they were due to changes of temperature and, possibly, to some extent, to shrinkage of the setting mortar, that they were not given serious consideration until Mr. Hill's attention was called to them, and by him they were considered so serious that his first report and recommendation that the core-wall be removed were very largely based upon them."

In reply to this, the speaker would state that he cannot concur in the opinion that the cracks were due to changes in temperature, as he could not expect contraction cracks to occur so closely together as five within a distance of 100 ft.; neither could he believe that they were caused by the shrinkage of the setting mortar, as such cracks could not extend through the wall, as they did in this case. But let the cause of the cracks be what it may, the cracks themselves were given importance by the speaker only inasmuch as they led him to a closer study of the plan, which study brought to light the really

Mr. Hill. objectionable features, as shown by his report to the Aqueduct Commissioners, dated May 15th, 1901, wherein he reported that the core-wall was cracked, pointed out the objectionable features, and recommended that they appoint a committee of engineers to pass upon the adequacy of the plan. The following is quoted from that report:

"Even though there were no cracks, I consider that it would be unwise to complete the structure under the present plan, as I consider it would be an experiment."

Hence, the recommendation to remove the core-wall was not based on the existence of the cracks, but solely upon the opinion that the plan was inadequate. The concluding paragraph of that report is as follows:

"I make this recommendation after carefully studying the situation and plan, and I know that I am absolutely right, but, still I feel that it is due to you, as well as to myself, that we should be fortified by the opinion of three prominent engineers in this most important matter, and I respectfully ask you to take the necessary action."

The Commissioners, after personal investigation, agreed to this and appointed a committee of expert engineers, consisting of Messrs. J. J. R. Croes, Past-President, Am. Soc. C. E.; Edwin F. Smith, M. Am. Soc. C. E., Chief Engineer of the Schuylkill Navigation Company; and Elnathan Sweet, M. Am. Soc. C. E., former Engineer of the State of New York. The committee, after making an investigation, reported unanimously recommending the removal of the core-wall and the extension of the stone dam.

The general public will no doubt feel that great weight has been added to these conclusions by the concurrence of the eminent engineers, William H. Burr, M. Am. Soc. C. E., occupying the Chair of Engineering of Columbia University, and Nelson P. Lewis, M. Am. Soc. C. E., Chief Engineer of the Board of Estimate and Apportionment of the City of New York, both of whom had been asked by Mayor Low to investigate and report thereon. On April 16th, 1902, the Aqueduct Commissioners resolved to remove the embankment and core-wall and to continue the main stone dam.

Mr. Gowen's paper contains two general contentions; one, that the plan of September 16th, 1896, was adequate; the other, that the natural foundation of the core-wall was safe.

To take up the first contention, that is, of the adequacy of the plan. This paramount question is treated in a brief manner, and without giving a clear description of the part of the plan under consideration. The only cross-section accompanying the paper is one of the embankment and core-wall at a point about 170 ft. from the end of the stone dam. In reference to this point, it states that

the original ground is only 20 ft. below ordinary high-water mark, and that the core-wall, 110 ft. high, was built in a trench 80 ft. deep. Mr. Hill.

The paper contains what he designates as a developed section, and this also passes through the core-wall at the same point, that is, about 170 ft. from the end of the stone dam, and, after passing through the core-wall, the section then follows on the so-called line of least resistance to the pressure and passage of water under or through the core-wall. This line is not a straight line at right angles to the structure, for it makes an abrupt angle on each side of the wall, both deflecting northerly; in fact, the up-stream line follows the top of the embankment to its end, and these two lines on opposite sides of the wall diverge from each other at an angle of only 45 degrees. On this crooked section, the author states:

"The thickness of the bank at ordinary high-water elevation is about 200 ft. and the thickness of the core-wall given at Elevation 80, if the hardpan be taken into account and included, is about 300 ft."

Here, it might be interesting to note that, on a true cross-section, the bank was to be 30 ft. thick at the top, while the wall at the elevation noted was to be only 17 ft. thick. The paper also states that, on the developed section, the slope of the embankment on the up-stream side is about 4 to 1. This is a mistake, as both the contract drawings and the plan accompanying the paper itself show the slope to be only 2 to 1.

Accompanying the paper is a plan showing in outline the section of embankment and core-wall between the end of the dam and the gate-house, a distance of about 275 ft., and a profile of the same showing the original ground and rock surface and the rock surface as excavated for the core-wall foundation.

Only two reasons are given to support the contention that the plan was adequate: One is a reference to a mass of hardpan covering the southern slope of the valley; the other is a denial of a statement that flowage of water is likely to occur along the face of the core-wall. What might be termed another reason is a citation of several dams that have been successfully built to heights ranging from 100 to 120 ft. As to the success of such structures, the paper contains the following:

"And it is a matter of common knowledge to those interested that there is no record extant of the failure of an earthen dam with a core-wall due to filtration through or under the wall and the consequent movement of the down-stream bank."

In reply to this the speaker would state that the records show that the Mill River Reservoir Dam, at Williamsburgh, Mass., burst on May 16th, 1874. It was an earthen dam, with a masonry core-

Mr. Hill. wall 600 ft. long and 43 ft. high. Water found its way under the core-wall and destroyed the embankment. The reservoir was suddenly emptied into a narrow valley, causing the loss of 140 lives and the destruction of about $1 000 000 worth of property.

The author also makes a reference to two rejoinders to the report of the Committee of Expert Engineers, when, without giving any information as to the contents of those rejoinders, his deduction from them is that they would seem to have covered completely and fully all the points advanced by the expert engineers and disposed of their conclusions effectively.

The foregoing constitutes all the information contained in the paper, concerning the dimensions and general features of the structure, and the reasons to support the contention that the plan was adequate. Upon these, so far as the paper is concerned, is based the conclusion:

"That the City of New York has expended unnecessarily nearly $1 000 000 and has failed to utilize at least two years of valuable time during which these changes at the New Croton Dam were being carried out."

The speaker, before presenting his view regarding the stability of the plan, deems it necessary to give the following brief description of the part of the embankment and core-wall under consideration. It extended from the end of the stone dam a distance of about 275 ft. to a gate-house built in the embankment. The core-wall at the end of the stone dam, as before stated, was to have a height of 200 ft., and, at the gate-house, a height of 90 ft. The embankment was to be 30 ft. wide at the top, with sides sloping in the ratio of 2 horizontal to 1 vertical. The lower portion of the inner slope, to a height of 16 ft. below the crest of the spillway, was to be paved with stone, 18 in. thick, laid dry, upon 12 in. of broken stone; and, on the upper part of the slope, to a height of 12 ft. above the crest of the spillway, the paving stone was to be 2 ft. thick, upon 18 in. of broken stone. The core-wall in the center of the embankment was to be 4 ft. higher than the crest of the spillway, 6 ft. wide at the top and increasing to 18 ft. at a depth of 136 ft., then it had the same width to the base. The high end of the core-wall had been built in a wide pit. That was a necessary excavation for the end of the stone dam, which was 164 ft. wide at the base, while the core-wall was only 18 ft. at its base. The slope of this pit extended southerly along the line of the core-wall for a distance of 150 ft.; thus the core-wall at its highest end was not built in a narrow trench below the surface of the ground, as is usual in ordinary cases. The outline of this great pit is shown on the plan accompanying the paper, and is marked "Top of Excavation."

There are in the plan three objectionable features which in-

fluenced the speaker to recommend the removal of the embankment and core-wall. They are as follows: First, the excessive height, narrow base, and unstable foundation of the embankment; second, the great height of the core-wall; and, third, the means afforded water to reach the core-wall. Mr. Hill.

To take up the first, the embankment: It was to be 150 ft. high, and only 650 ft. thick at the base. This section would be not only about 30% higher than any heretofore built, but, in comparison with other high embankments, its base was narrow for its height. As an example, the Amawalk Dam, which forms one of the upper Croton Reservoirs, while only about half the height, 85 ft., yet has a base wider than that of this embankment of unprecedented height; and, further, this embankment was hazardous because of the unstable nature of its foundation. It was founded over a great refilled pit, which was 360 ft. wide at the top, 170 ft. at the base and 70 ft. deep. This pit was a necessary excavation for the foundation of the end of the stone dam, which was 164 ft. wide at the base, as before stated. It would be impossible to refill this pit as compactly as the original hardpan; hence the safety of the reservoir was dependent not only on an embankment of a problematic section, but this problematic section rested upon an unstable foundation.

The second of the objections: The core-wall of this embankment was to have the great height of 200 ft. and with no lateral protection or support whatsoever from the original ground, as the artificially placed earth on each side of the wall in this wide pit had the height of the wall itself, 200 ft. The natural hardpan would afford no protection whatsoever here, inasmuch as it had been excavated to its entire depth; in fact, the underlying rock had been removed to a depth of about 15 ft. Considering the height of the wall, and this in artificially placed earth, it could be but an experimental structure, inasmuch as it would be about twice the height of any heretofore built.

The third objection, the means afforded the water to reach the core-wall: This is another serious objection, as the water, by starting at the end of the embankment in the reservoir and following between the face of the stone dam and the embankment, would inevitably reach the core-wall. It would be impossible to puddle or otherwise compact the embankment against the dam to prevent this, as settlement would surely follow in any embankment of this great height, and the settlement of the material under the projecting parts of the rock-faced masonry would leave cavities for the passage of water. This objectionable feature here exists because of the combination of a stone dam and an embankment, while it could not exist in either a continuous stone dam or, on the other hand, a continuous embankment and core-wall.

Mr. Hill. A fourth objection might here be stated, namely, the permeable and light character of the earth of which the embankment was made. Relating to this material, the Committee of Engineers reported:

"It is permeable to water under any head from 3 to 150 ft., and, when exposed to the direct action of water, it disintegrates and assumes a flat slope, the surface of which is best described as slimy."

Thus it will be seen that the safety of this reservoir was dependent, not only upon an embankment made of permeable material and of a problematic section resting upon an unstable foundation, but also upon a core-wall of phenomenal height, unprotected and unsupported by original soil and attended with the greatest of all possible risks; that is, the means afforded water to reach the center of the embankment against the core-wall. Such a structure, in the speaker's opinion, cannot be regarded as anything but an experiment, as it is abnormal and unprecedented in all its dangerous features. Thus, as the speaker was thoroughly convinced that the plan was inadequate, he was left no alternative but to condemn it.

Before closing, the speaker wishes to state that he has no desire to discuss the contention that the natural foundation of the core-wall was safe, as he wishes to maintain the stand he took at first; that is, that the plan of the structure itself was faulty, without considering the physical conditions existing below the base of the core-wall, and that the modification of the plan has resulted in the completion of the structure in keeping with the report of the Board of Expert Engineers, consisting of Messrs. J. J. R. Croes, Joseph P. Davis and William F. Shunk, who, in 1888, recommended that the Quaker Bridge Dam, for which this is a substitute, be a stone structure from end to end.

Mr. Stearns FREDERIC P. STEARNS, PRESIDENT, AM. SOC. C. E. (by letter).—Mr. Gowen's paper presents in a very clear way the conditions surrounding the dike of questionable limestone found at the southerly end of the dam, and he gives convincing reasons in support of the view that the construction, as originally planned and, to a large extent, executed at that place, was entirely safe. The writer has never examined this limestone, but he has had occasion to make tests of the bearing capacity of other soft rock, using for the purpose apparatus copied from that used for testing foundations at the New Croton Dam, and was surprised to find what a great difference there was between a very soft rock and the hardest and most compact earth. Therefore, he would expect any rock found in this section of the country to support a weight equal to that of a masonry core-wall.

The permeability of a rock foundation, where the rock is of compact texture, depends upon the presence of seams or other passages

for water, and not in any degree upon whether the rock is hard or soft. Mr. Stearns.

In a case like that described, where the core-wall was built in a narrow trench cut in firm hardpan extending to the rock, and where there was also provided an embankment of fine clayey material of great dimensions, there must be taken into account the resistance of this earth to seepage and to water pressure.

It is quite often the case that an embankment built of earth containing a sufficient proportion of fine particles is as nearly water-tight as a concrete or other masonry core-wall, but this is not recognized in all instances, possibly because the concrete has so much greater strength.

The Board of Expert Engineers, who recommended the changes at the New Croton Dam, caused many borings to be made in the embankments of the dams of the Croton system, and, in a majority of cases, the line of saturation determined by the investigations indicated no greater resistance to seepage or percolation at the core-wall than in the embankment of earth.

In view of the character of the earth at the part of the New Croton Dam under consideration and the great distance through the earth on the line of least resistance, the writer is of the opinion that the dam would have stood at this point without any core-wall, provided the up-stream part of the embankment of clayey material were carried down to join the hardpan, and that, with the core-wall as an added safeguard, this part of the dam would have had a greater factor of safety than the all-masonry section.

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# PAPERS AND DISCUSSIONS.

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## TEST OF A THREE-STAGE, DIRECT-CONNECTED CENTRIFUGAL PUMPING UNIT.

### Discussion.*

By Elmo G. Harris, M. Am. Soc. C. E.

Mr. Harris.

Elmo G. Harris, M. Am. Soc. C. E. (by letter).—It is a matter to be regretted that, under the pressure of severe competition, manufacturers of centrifugal pumps claim, and will often guarantee greater efficiencies than their machines can give; but there is no hope of bringing about the desired reform except by enforcing these guaranties. If this were commonly done, it would result in a two-fold benefit: first, by preventing a mild degree of fraud on credulous purchasers; and, second, by ultimately improving the machines, until the efficiency is brought up to what the well informed believe to be economically attainable.

If the equivalent of the following clause were inserted in contracts for the purchase and installation of centrifugal pumps, the makers would be very conservative in their guaranties of efficiency, and, further, it would reveal to all parties concerned an economic principle too often neglected in fixing the cost of various installations:

"The contractor guarantees an efficiency of ( ) per cent., as determined by dividing the power delivered to the pump shaft by the power (due to the pump) in the water taken immediately after leaving that portion of the plant for which the contractor is re-

*Continued from December, 1905, *Proceedings*. See December, 1905, *Proceedings*, for paper on this subject by Philip E. Harroun, M. Am. Soc. C. E.

sponsible; and should this efficiency not be realized, the deficit, under normal working conditions, shall be estimated in horse powers, and, assuming the value of 1 h. p. to be ($ ) per annum, the present value of such a sum, paid annually for ( ) years, shall be estimated under a rate of interest of ( ) per cent. per annum, and this sum shall be deducted from the contract price of the pumping plant * * *." Mr. Harris.

If a corresponding bonus should be offered for exceeding a stated efficiency, the rapid improvement of centrifugal pumps would be assured. Much of the fault is due to the indifference or ignorance of the purchaser.

In regard to needed experimental knowledge, little is known about the losses caused by the friction of water gliding over metallic surfaces at such velocities as exist in centrifugal pumps. This should be found for revolving disks varying in diameter, surface finish, and speed. Considering the value of such data, the cost of the necessary apparatus would be small.

The answer to Mr. Richards' question, as to why efficiency should be insisted upon in centrifugal pumps and not in direct-acting reciprocating pumps, is that the cost of the power going into a centrifugal pump is very much greater than that going into a direct-acting pump; the latter is a cheap affair in first cost, taking steam direct from the boiler, while for a centrifugal pump there must be a rotating engine of some sort, and, if the pump is driven by electricity, there must be the prime motor (steam engine or water-wheel), the dynamo and the electric motor.

Noting Mr. Richards' allusion to a scheme for compressing air by combining air and water in a centrifugal machine, the writer would call attention to the Appendix* to the paper entitled, "Theory of Centrifugal Pumps and Fans," where such a scheme is somewhat clearly outlined.

Professor Le Conte was probably too modest to mention his excellent report of tests of centrifugal pumping plants published in the United States Report of Irrigation and Drainage Investigations, 1904. Such matter is scarce and valuable.

* *Transactions*, Am. Soc. C. E., Vol. LI, p. 222.

# MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

## GABRIEL LEVERICH, M. Am. Soc. C. E.*

DIED NOVEMBER 28TH, 1905.

Gabriel Leverich was born on a farm about five miles from Elmira, New York, on August 19th, 1834. He was the son of Samuel and Sarah Leverich, for many years residents of New York City.

In his early years he attended what was then called the District (public) school in the vicinity, where he excelled in all his studies.

His taste seemed to be decidedly for mechanical work, and among his early inventions were a hay-rake, much like the one now generally used; a hay-fork for use by horse power, and other ingenious and practical inventions.

Two intimate friends and near neighbors, of about his own age, were graduates of the Rensselaer Polytechnic Institute, and this led him also to attend the institute, from which he was graduated in 1857.

His first engagement, after graduation, was at the Trenton Locomotive Works, where machinery for the manufacture of small arms was about to be introduced. In this connection he spent some time at the works near Springfield, Massachusetts, obtaining data from which he designed and constructed the necessary tools.

At this time Mr. Wiard was at Trenton, engaged in the construction of heavy ordnance embodying proposed improvements, and Mr. Leverich became interested in the matter. This, at a later date, led to his employment at Boston in the design of the "Thompson gun." The writer does not remember the details of this, but Mr. Leverich was one of the first to shrink on a jacket or insert a lining. This involved the refined accuracy of measurement with which we are now so familiar.

Other enterprises with which he was intimately connected were: the design and construction of apparatus for the destructive distillation of wood, in which all the products were saved; also, of machinery for the manufacture of fuel briquettes, by the compression of peat; and of improvements in the propulsion of tram cars.

Mr. Leverich was elected a Member of the American Society of Civil Engineers on July 6th, 1870, and from 1872 to 1877, inclusive,

*Memoir prepared by Francis Collingwood, M. Am. Soc. C. E.

served as Secretary of the Society. In these trying years of the Society's history, while nominally receiving a fair salary, he spent a considerable proportion of it in paying expenses which he deemed essential for its advancement, and for which the income was insufficient. Only his most intimate friends knew of this, however.

His services upon the first East River Bridge began when the approaches were under construction. He was responsible for the general features of the design of the Franklin Square Bridge, where the complexities of construction were very considerable. He took an important part, also, in the design of the New York station; and had entire charge of the changes, in both the New York and Brooklyn stations, made necessary by the great increase in traffic. These have more than doubled the carrying capacity of the bridge.

The rapid growth of traffic made it necessary also to improve the apparatus for propelling the cars on the bridge and increase its power. In carrying this out, Mr. Leverich showed an accurate knowledge of mechanical devices, and of the principles of mechanics; and the machinery is a model of ingenuity and effectiveness. This apparatus is described in a paper by him in Vol. XVIII of the *Transactions* of the Society. He contributed several other papers and discussions to the *Transactions*. All are noted for their clearness and accuracy of thought and expression. This was characteristic of all his work, and enabled him to answer all objections and carry his plans through to completion.

He died at the age of 71, having been an invalid for about six years, leaving a widow and a married daughter.

Mr. Leverich was bright and cheerful in disposition, and a good conversationalist. He was generous to a fault, and often, to his own detriment, helped others. He kept fully posted in all professional, industrial and political matters.

In early life he joined the Episcopal Church, and was always interested in its welfare.

# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

OF

# CIVIL ENGINEERS.

(INSTITUTED 1852.)

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VOL. XXXII. No. 3.

MARCH, 1906.

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Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

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**Society Affairs**.....Pages 109 to 136.
**Papers and Discussions**.....Pages 167 to 286.

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NEW YORK 1906.

Entered according to Act of Congress, by the AMERICAN SOCIETY OF CIVIL ENGINEERS, in the office of the Librarian of Congress, at Washington.

# American Society of Civil Engineers.

## OFFICERS FOR 1906.

*President*, FREDERIC P. STEARNS.

*Vice-Presidents.*

| *Term expires January, 1907:* | *Term expires January, 1908:* |
|---|---|
| M. L. HOLMAN, | ONWARD BATES, |
| E. KUICHLING. | BERNARD R. GREEN. |

*Secretary*, CHARLES WARREN HUNT.

*Treasurer*, JOSEPH M. KNAP.

*Directors.*

| *Term expires January, 1907:* | *Term expires January, 1908:* | *Term expires January, 1909.* |
|---|---|---|
| CHARLES S. GOWEN, | AUSTIN L. BOWMAN, | GEORGE GIBBS, |
| NELSON P. LEWIS, | MORRIS R. SHERRERD, | J. WALDO SMITH, |
| JOHN W. ELLIS, | HEZEKIAH BISSELL, | EMIL SWENSSON. |
| GEORGE S. WEBSTER, | EDWIN A. FISHER, | JAMES M. JOHNSON, |
| RALPH MODJESKI, | WILLIAM B. LANDRETH, | WYNKOOP KIERSTED, |
| CHARLES D. MARX. | GEORGE S. PIERSON. | WILLIAM B. STOREY, JR. |

*Assistant Secretary*, T. J. McMINN.

## Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

| *On Finance:* | *On Publications:* | *On Library:* |
|---|---|---|
| EMIL KUICHLING, | MORRIS R. SHERRERD, | NELSON P. LEWIS, |
| CHARLES S. GOWEN, | J. WALDO SMITH, | AUSTIN L. BOWMAN, |
| GEORGE GIBBS, | ONWARD BATES, | RALPH MODJESKI, |
| M. L. HOLMAN, | BERNARD R. GREEN, | HEZEKIAH BISSELL, |
| GEORGE S. PIERSON. | GEORGE S. WEBSTER. | CHARLES WARREN HUNT. |

## Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON RAIL SECTIONS:—Joseph T. Richards, C. W. Buchholz, E. C. Carter, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

ON CONCRETE AND REINFORCED CONCRETE:—C. C. Schneider, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, J. W. Schaub, Emil Swensson, A. N. Talbot, J. R. Worcester.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER: - - - 533 Columbus.
CABLE ADDRESS: - - - "Ceas, New York."

Vol. XXXII. MARCH, 1906. No. 3.

# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## SOCIETY AFFAIRS.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

**March 7th, 1906.**—The meeting was called to order at 8.40 P. M.; Vice-President Kuichling in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 104 members and 18 guests.

The minutes of the meetings of February 7th, 14th and 21st, 1906, were approved as printed in the *Proceedings* for February, 1906.

A paper by Ernst F. Jonson, Assoc. M. Am. Soc. C. E., entitled "The Theory of Continuous Columns," was presented by the author.

Ballots for membership were canvassed, and the following candidates elected:

AS MEMBERS.

PHILIP HENRY COOMBS, Bangor, Me.
FREDERICK LEMAN GARLINGHOUSE, Pittsburg, Pa.
JOHN FRANCIS MURRAY, Lancaster, Pa.

EMERY OLIVER, Oroville, Cal.
ARTHUR BREESE PROAL, JR., New York City.
EDWIN CHARLES SWEZEY, Brooklyn, N. Y.
THOMAS MONROE WARD, Baltimore, Md.

AS ASSOCIATE MEMBERS.

HENRY JAMES ALEXANDER, New York City.
WALTER LORING ANTHONY, Providence, R. I.
WALTER BUEHLER, Minneapolis, Minn.
WARREN VESTER CLARK, Berkeley, Cal.
VERNON ROYCE COVELL, Pittsburg, Pa.
PHILIP HENRY FALTER, Shawinigan Falls, Que., Canada.
RAMIRO FERRADAS, New York City.
JOHN PEDEN GARDINER, New York City.
JOHN STANTON GOODELL, Cleburne, Tex.
STEPHEN FORD HOLTZMAN, New York City.
FRANCIS REA JONES, Topeka, Kans.
CHARLES WHITESIDE KEITH, Chicago, Ill.
ELSWORTH MORTIMER LEE, New York City.
RICHARD DENNY PARKER, Houston, Tex.
GEORGE LOOMIS ROBINSON, New York City.
GEORGE OTIS SANFORD, Glendive, Mont.
HORACE RICHMOND THAYER, South Bethlehem, Pa.
JEROME FREDERICK WILHELM, Paragould, Ark.
ROGER BUTLER WILLIAMS, JR., New York City.

AS ASSOCIATES.

DANIEL GRIFFITH AMBLER, Washington, D. C.
HAROLD BOUTON, New York City.

The Assistant Secretary announced:

The transfer of the following candidates, by the Board of Direction, on March 6th, 1906:

FROM ASSOCIATE MEMBER TO MEMBER.

GEORGE BAUM, Niagara Falls, Ont., Canada.
ARTHUR LINCOLN DAVIS, New York City.
ALFRED COURTNEY LEWERENZ, Bremerton, Wash.
ENOS LARKIN SHAW, Chicago, Ill.
IRVING SPARROW WOOD, Providence, R. I.

FROM ASSOCIATE TO MEMBER.

EDWARD LORENZO ABBOTT, New York City.

The election of the following candidates, by the Board of Direction:

AS JUNIORS.

On February 6th, 1906:

ARTHUR CASSIDY EVERHAM, Detroit, Mich.
NORMAN ROOSEVELT MCLURE, Ardmore, Pa.
WILLIAM THOMAS PIPER, Nashville, Tenn.

On March 6th, 1906:

NORA STANTON BLATCH, New York City.
HOWARD EMORY BUSHNELL, Hartford, Conn.
WILLIAM PEYTON DAY, San Francisco, Cal.
ROGER DELAND FRENCH, Worcester, Mass.
ELBERT ALLAN GIBBS, Ithaca, N. Y.
CHARLES EDWARD HAYES, Cincinnati, Ohio.
HOWARD BENSON WILBERFORCE HOWIE, Chattanooga, Tenn.
ARTHUR JAMES MCNEIL, Whittier, Cal.
VINCENT ROBERTS, New York City.

Adjourned.

**March 21st, 1906.**—The meeting was called to order at 8.40 P. M., Vice-President Kuichling in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 148 members and 28 guests.

A paper, by Theodore Cooper, M. Am. Soc. C. E., entitled "New Facts about Eye-Bars," was presented by the author.

The Assistant Secretary presented written communications on the subject from Messrs. Albert J. Himes, A. W. Carpenter and John Thomson, and the paper was discussed orally by Messrs. H. B. Seaman, Mansfield Merriman, Mace Moulton and the author.

The Assistant Secretary announced the following deaths:

JOHN JAMES ROBERTSON CROES, Past-President, Am. Soc. C. E., elected Member, December 4th, 1867; President, January 16th, 1901, to January 15th, 1902; Vice-President, January 18th, 1888, to January 16th, 1889; Treasurer, November 7th, 1877, to January 18th, 1888, and Director, November 1st, 1876, to November 7th, 1877; died March 17th, 1906.

WILLIAM THOMAS PIERCE, elected Member, May 6th, 1896; died March 10th, 1906.

PER BRYNN, elected Associate Member, February 4th, 1903; died February 10th, 1906.

Adjourned.

## OF THE BOARD OF DIRECTION.

(Abstract.)

**March 6th, 1906.**—President Stearns in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary, and present, also, Messrs. Bissell, Bowman, Ellis, Gowen, Green, Knap, Kuichling, Lewis, Noble, Schneider, Sherrerd, Swensson, and Webster.

The following committee was appointed to take charge of the arrangements for the Annual Convention:

Messrs. Charles S. Gowen, John W. Ellis, J. Waldo Smith, Morris R. Sherrerd, and Chas. Warren Hunt.

Applications were considered, and other routine business transacted.

Five Associate Members were transferred to the grade of Member, one Associate was transferred to the grade of Member, and nine candidates for Junior were elected.

Adjourned.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, April 4th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Panama Canal," by A. G. Menocal, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for February, 1906.

**Wednesday, April 18th, 1906.**—8.30 P. M.—At this meeting a paper, entitled "A Complete Analysis of General Flexure in a Straight Bar of Uniform Cross-Section," by L. J. Johnson, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for February, 1906.

**Wednesday, May 2d, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Control of Hydraulic Mining in California by the Federal Government," by William W. Harts, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for February, 1906.

**Wednesday, May 16th, 1906.**—8.30 P. M.—At this meeting a paper, entitled "The Scranton Tunnel of the Lackawanna and Wyoming Valley Railroad," by George B. Francis and W. F. Dennis, Members, Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

### ANNUAL CONVENTION.

The Thirty-eight Annual Convention of the Society will be held at The Hotel Frontenac, Thousand Islands, New York, on June 26th to 29th, 1906.

The general arrangements for the Convention are in the hands of the following Committee:

CHARLES S. GOWEN,
JOHN W. ELLIS, MORRIS R. SHERRERD,
J. WALDO SMITH, CHAS. WARREN HUNT.

## PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 410 Penn Avenue, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner, Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten- Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesbrough, England.

**Civil Engineers' Society of St. Paul,** St. Paul, Minn.

**Koninklijk Instituut van Ingenieurs,** The Hague, The Netherlands.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

# ACCESSIONS TO THE LIBRARY.

From February 14th to March 13th, 1906.

## DONATIONS.*

### MANUAL OF EXAMINATIONS FOR ENGINEERING POSITIONS

In the Civil Service of the City of New York. Questions and Answers in 3 volumes. Vol. I, Part IV, Transitman and Computer; Vol. II, Part I, Assistant Engineer, Rapid Transit Commission. Paper, 9 × 6 in., illus., 2 parts. New York, The Engineering News Publishing Company, 1906. Vol. I, Part IV, 50 cents; Vol. II, Part I, 75 cents.

The preface states that in the "Previous Examination Papers" which have been included in this book, the questions may not, in all cases, be identical in wording with those actually given at the examinations, as copies of the original papers are not readily procurable, but they do embody the substance of the questions asked. In the section devoted to "Typical Questions and Answers," it is stated, that the answers indicate only in a general way what is required of the candidate, and are not intended to be perfect and complete, as reasonable variance of opinion may exist as to the best answer in many cases, owing to differences in interpretations of the question and in education and experience. Blank leaves have been inserted after the "Previous Examination Papers" to allow for the convenient addition of new sets, and the "Typical Questions and Answers" have been interleaved in order to provide space for notes, sketches and additions.

### ELECTRIC POWER TRANSMISSION.

A Practical Treatise for Practical Men. By Louis Bell. Cloth, 9 × 6 in., illus., 721 pp. New York, McGraw Publishing Company, 1906. $4 net.

The preface states that, although there have been very few sensational changes in electric power transmission, the aggregate of minor changes in the past three years has made a new edition imperative. The author has found it needful to devote some special attention to the important accessory apparatus of which modern stations are full, and to make use of considerable new material of a more general sort, as well as to eliminate some descriptive matter which had to do with things which are obsolete and without historical importance. It is stated that in retaining merely as a matter of general interest a list of high voltage transmission plants nothing under 20 000 volts is included, as it has now become a hopeless task to keep track of 10 000 volt plants. There is an index of sixteen pages.

### PRACTICAL ELECTRIC RAILWAY HAND BOOK.

By Albert B. Herrick. Second Edition, Revised and Corrected. Leather, 7 × 4 in., illus., 460 pp. New York, McGraw Publishing Company, 1906. $3 net.

The preface states that in this edition a number of sections have been rewritten and expanded, and new subjects have been introduced to accord with recent developments in the electric transportation industry. New methods of testing have also been described, and data on new types of apparatus have been added. It has been the author's effort to develop this Hand Book along the lines originally proposed and to keep within the limits of what is accepted as conservative engineering. He has also restricted the use of formulas and mathematics as far as possible, so as to make the text useful to the greatest number of co-laborers in this field. There is an index of nine pages.

### MODERN TUNNEL PRACTICE.

Illustrated by Examples taken from Actual Recent Work in the United States and in Foreign Countries. By David McNeely Stauffer, M. Am. Soc. C. E. Cloth, 10 × 7 in., illus., 8 + 314 pp. New York, Engineering News Publishing Company, 1906. $5 net.

The preface states that, in the arrangement of this work, especial effort has been made to present modern practice in tunneling under as many varying conditions as possible, and to describe clearly and concisely the methods

*Unless otherwise specified, books in this list have been donated by the publisher.

actually adopted in carrying on the work under certain controlling conditions. The material used is very largely taken from the detailed descriptions found in the pages of technical journals and in the proceedings of engineering societies, supplemented by the personal experience of engineers and contractors. Illustration is very freely used. It is stated that the description of any especial method is prefaced by a brief statement of the physical conditions which called for some particular treatment. It is intended that the examples cited should be typical modern cases and cover a wide range of practice; no attempt has been made to include every important tunnel. What is said here on the subject of surveying is meant simply as a general statement of the processes involved and of their sequence. The composition, nature and use of modern explosives have been treated at considerable length; but much has been left out that was considered as having little bearing on tunnel building. There is a glossary of unusual terms used in tunneling and an index of six pages.

Gifts have also been received from the following:

Abner Doble Co. 4 pam.
Alabama—Geol. Surv. 1 map.
Am. Ceramic Soc. 1 vol.
Assoc. of Ry. Supts. of Bridges and Bldgs. 1 vol.
Baltimore, Md.—Harbor Board. 1 pam.
Behr, H. C. 1 vol.
Canada—Hydrographic Surv. 4 maps.
Cape of Good Hope—Dept. of Public Works. 1 vol.
Chicago, Peoria & St. Louis Ry. Co. 1 pam.
Cincinnati, Hamilton & Dayton Ry. Co. 1 pam.
Committee of Locomotive, Carriage and Wagon Supts. for Indian Railways. 1 bound vol.
Hague, C. A. 2 pam.
Iron and Steel Inst. 1 bound vol.
King, G. A. and W. B. 2 pam.
Kirchoffer, W. G. 1 vol.
Königlichen Tech. Hochschule zu Berlin. 1 pam.
Koninklijk Inst. van Ingenieurs. 1 pam.
Lake Mohonk Conference of the Friends of the Indian and other Dependent Peoples. 1 vol.
Maryland—Geol. Surv. 1 bound vol.
Mead, Elwood. 8 pam.
Mich.—State Board of Health. 1 bound vol.
Mich. Univ. Eng. Soc. 1 pam.
Millard, J. H. 18 pam.
National Board of Fire Underwriters Committee of Twenty. 2 pam.
New South Wales—Govt. Statistician. 1 pam.
New York State—Board of R. R. Commrs. 2 bound vol.
New York State—Museum. 2 bound vol.
North of England Inst. of Min. and Mech. Engrs. 2 pam.
Platt, T. C. 1 vol.
Poor's R. R. Manual Co. 1 vol.
Schenectady, N. Y.—City Engr. 2 pam.
Smith, J. A. 1 pam.
South Australia—Public Works Dept. 1 vol.
Thompson, R. A. 1 pam.
U. S. Bureau of Labor. 1 vol.
U. S. Forest Service. 5 pam.
U. S. Geol. Surv. 6 vol., 99 maps.
U. S. Interstate Commerce Comm. 3 bound vol.
U. S. Isthmian Canal Comm. 1 pam.
U. S. Lake Survey Office. 5 maps.
U. S. Naval War Records Office and Library. 1 vol.
U. S. Office of Public Road Inquiries. 3 pam.
U. S. Secy. of War. 4 bound vol.
Univ. of Pennsylvania. 1 vol.
Wellington, New Zealand—Harbour Board. 1 pam.
Western Australia—Govt. Rys. 1 vol.

## BY PURCHASE.

**The Irrigation Works of India.** By Robert Burton Buckley. Second Edition. London, E. & F. N. Spon, Ltd.; N. Y., Spon & Chamberlain, 1905.

**The Nature of Ore Deposits.** By Richard Beck; Translated and Revised by Walter Harvey Weed. Vols. 1–2. New York and London, The Engineering and Mining Journal, 1905.

**A Handbook of Rocks** for Use Without the Microscope. By James Furman Kemp. Third Edition Revised. New York, D. Van Nostrand Company, 1906.

**The Mineral Industry During 1904.** Vol. XIII. New York and London, The Engineering and Mining Journal, 1905.

**Die Entwickelung des Niederrheinisch-Westfälischen Steinkohlen-Bergbaues** in der zweiten Hälfte des 19 Jahrhunderts. Vol. VIII.—Disposition der Tagesanlagen, Dampferzeugung, Centralkondensation, Luftkompressoren, Elektrische Centralen. Berlin, Julius Springer, 1905.

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## SUMMARY OF ACCESSIONS.

February 14th to March 13th, 1906.

| | |
|---|---|
| Donations (including 15 duplicates)..... | 213 |
| By purchase..... | 6 |
| Total ..... | 219 |

## MEMBERSHIP.

### ADDITIONS.

#### MEMBERS.

| | | Date of Membership. |
|---|---|---|
| ABBOTT, EDWARD LORENZO. 71 Broadway, New York City | Jun. | Sept. 1, 1886 |
| | Assoc. | April 30, 1895 |
| | M. | Mar. 6, 1906 |
| BALLINGER, WALTER FRANCIS. S. W. Cor. 12th and Chestnut Sts., Philadelphia, Pa. | | Feb. 7, 1906 |
| BARNSLEY, GEORGE THOMAS. Chf. Road Engr., Allegheny County, Court House, Pittsburg (Res., Oakmont), Pa. | Jun. | May 31, 1892 |
| | Assoc. M. | May 7, 1894 |
| | M. | Feb. 6, 1906 |
| DAHM, SVERRE. Gen. Insp. of Designs, Rapid Transit R. R. Comm., 320 Broadway, New York City. | | Feb. 7, 1906 |
| HAAS, EDWARD FRANCIS. 320 Sansome St., San Francisco, Cal. | Jun. | Feb. 6, 1894 |
| | Assoc. M. | Sept. 5, 1900 |
| | M. | Feb. 6, 1906 |
| HAMMOND, GEORGE TILLINGHAST. 156 Berkeley Pl., Brooklyn, N. Y. | | Feb. 7, 1906 |
| HAMMOND, JOHN FARNSWORTH. 335 Flatbush Ave., Brooklyn, N. Y. | | Feb. 7, 1906 |
| HUNT, ANDREW MURRAY. Union Trust Bldg., San Francisco, Cal. | | Feb. 7, 1906 |
| HUNTER, WILLIAM HENRY. Chf. Engr., Manchester Ship Canal, 41 Spring Gardens, Manchester, England. | | Feb. 7, 1906 |
| LENTILHON, EUGENE. Engr. for Chilean Contr. Co., 43 Exchange Pl., New York City. | Jun. | Mar. 1, 1891 |
| | Assoc. M. | Mar. 6, 1895 |
| | M. | Feb. 6, 1906 |
| LEPPER, FRED WILLIAM. Supt., Constr. of Public Bldgs., 504 Chamber of Commerce Bldg., Cleveland, Ohio. | Assoc. M. | Jan. 2, 1901 |
| | M. | Feb. 6, 1906 |
| MOORE, WILLIAM EDWIN. Clarkston, Wash. | | Feb. 7, 1906 |
| MUESER, WILLIAM. 822 Park Row Bldg., New York City. | | Feb. 7, 1906 |
| RANDALL, HENRY IRWIN. Asst. Engr., S. P. R. R. Co., 2000 Durant Ave., Berkeley, Cal. | | Feb. 7, 1906 |
| SCHAEFFER, AMOS. Engr., Sewer Div., Rapid Transit R. R. Comm., 10 Bridge St. (Res., 2309 Loring Pl., University Heights), New York City. | Assoc. M. | Feb. 3, 1904 |
| | M. | Feb. 6, 1906 |

#### ASSOCIATE MEMBERS.

| | | |
|---|---|---|
| ALLARDICE, ELLIOT RITCHIE BARCLAY. Div. Engr., Met. Water and Sewerage Board, P. O. Box 38, Clinton, Mass. | | Dec. 6, 1905 |
| ANTHONY, WALTER LORING. Engr. in Chg., Providence Office, The R. H. Tingley Co., 75 Westminster St., Providence, R.I. | Jun. | Jan. 5, 1904 |
| | Assoc. M. | Mar. 7, 1906 |

ASSOCIATE MEMBERS (*Continued*).

| | | Date of Membership. |
|---|---|---|
| ARMSTRONG, ALEXANDER FLOYD. Supt., Water Supply and Sewers, Manila, Philippine Islands | Jun. | Oct. 7, 1902 |
| | Assoc. M. | Nov. 1, 1905 |
| BARLOW, DE WITT DUKES. City Engr., Cape May City, N. J. | | Feb. 7, 1906 |
| CORNISH, LORENZO DANA. U. S. Junior Engr., U. S. Engr. Office, Beaver, Pa | Jun. | April 5, 1904 |
| | Assoc. M. | Feb. 7, 1906 |
| CRAIG, GEORGE WASHINGTON. Asst. City Engr., Omaha, Nebr. | | Feb. 7, 1906 |
| DENCER, FREDERICK WILLIAM. Clybourn and Wrightwood Aves., Chicago, Ill. | | Feb. 7, 1906 |
| HALSEY, EDMUND RYOND. 164 Market St., Newark, N. J. | | Feb. 7, 1906 |
| HARRINGTON, HARRY GARFIELD. Eng. Dept., The New Jersey Zinc Co., 71 Broadway, New York City | Jun. | Jan. 7, 1902 |
| | Assoc. M. | Feb. 7, 1906 |
| HECKLE, GEORGE ROGERS. Hotel Vendome, Columbus, Ohio | | Feb. 7, 1906 |
| HOGUE, CHESTER JAMES. 101 Tremont St., Boston, Mass. | | Dec. 6, 1905 |
| JOUETT, HENRY DETRICK. 65 West 92d St., New York City | | Feb. 7, 1906 |
| KIRKHAM, JOHN EDWARD. Asst. Engr., Am. Bridge Co., Ambridge, Pa. | | Feb. 7, 1906 |
| MEADOWCROFT, WILLIAM. Iloilo, Paney, Philippine Islands | | Dec. 6, 1905 |
| MOORE, EGBERT JESSUP. Designing Engr. for The Turner Constr. Co., 11 Broadway, New York City (Res., 80 Cornell Ave., Yonkers, N. Y.) | Jun. | Mar. 31, 1903 |
| | Assoc. M. | Feb. 7, 1906 |
| NORTH, ARTHUR TAPPAN. Chf. Engr., National Fire Proofing Co. (Western Dept.), 806 Hartford Bldg., Chicago, Ill. | | Feb. 7, 1906 |
| OINOUYE, CHIKAO. With Pennsylvania Steel Co., Steelton, Pa. | | Feb. 7, 1906 |
| PERKINS, ALBERT HENRY. Engr., U. S. Reclamation Service, Cody, Wyo. | | Feb. 7, 1906 |
| PILL, JOHN RICHARDS. Gen. Supt., Galloway Coal Co., Carbon Hill, Ala. | | Feb. 7, 1906 |
| SCHUCHART, PAUL AUGUST. Chf. Engr., Bell Eng. & Constr. Co., 220 Broadway, New York City | | Feb. 7, 1906 |
| SPARROW, WILLIAM WARBURTON KNOX. Queenstown, Cape Colony, South Africa | | Dec. 6, 1905 |
| STONE, WILLARD WILBERFORCE. Care, Dr. Chas. Murphy, 74 West 35th St., New York City | | Feb. 7, 1906 |
| TROW, FRANK HAMANT. Div. Engr., Met. Water and Sewerage Board, 19 Leighton Ave., Clinton, Mass. | | Feb. 7, 1906 |

ASSOCIATE MEMBERS (*Continued*).

| | Date of Membership. |
|---|---|
| WELLES, EARLE HUBBEL. 3848 Prospect Ave., Cleveland, Ohio | Feb. 7, 1906 |
| WILLIAMS, SAMUEL WALTER. 244 Fifth Ave., New York City | Feb. 7, 1906 |
| WILLIAMSON, CHARLES SUMNER. Care, Heyl & Patterson, Inc., 52 Water St., Pittsburg, Pa | Feb. 7, 1906 |

ASSOCIATES.

| | |
|---|---|
| MOYER, ALBERT. Mgr. and Director, Vulcanite Portland Cement Co., Flatiron Bldg., New York City | Feb. 7, 1906 |
| WOODBURY, JOHN MCGAW. Commr. of Street Cleaning, 21 Park Row, New York City | Feb. 7, 1906 |

JUNIORS.

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|---|---|
| BRUA, ELMER GEORGE. Monterey, Cal | Feb. 6, 1906 |
| CROWELL, FRANCIS STIRLING. 188 Franklin Pl., Flushing, N. Y | Feb. 6, 1906 |
| EVERHAM, ARTHUR CASSIDY. M. C. Depot, Detroit, Mich. | Feb. 6, 1906 |
| MCLURE, NORMAN ROOSEVELT. Ardmore, Pa | Feb. 6, 1906 |
| METZGER, FRITZ LOUIS. Freedom, Pa | Feb. 6, 1906 |
| O'NEAL, ALFRED MOORE, JR. 1913 Amsterdam Ave., New York City | Jan. 2, 1906 |
| OWEN, KENNETH DUNHAM. Montclair, N. J | Feb. 6, 1906 |
| PIPER, WILLIAM THOMAS. 300 South 8th Ave., Nashville, Tenn | Feb. 6, 1906 |
| VAN KIRK, CHARLES HINKLEY. 4754 Greenwood Ave., Chicago, Ill | Jan. 2, 1906 |
| WORMSER, MORITZ. 120 West 57th St., New York City | Feb. 6, 1906 |

## DEATHS.

PIERCE, WILLIAM THOMAS. Elected Member, May 6th, 1896; died February 26th, 1906.

CROES, JOHN JAMES ROBERTSON. Past-President, elected Member, December 4th, 1867; died March 17th, 1906.

BRYNN, PER. Elected Associate Member, February 4th, 1903; died February 10th, 1906.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(February 10th to March 10th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefeuille Economique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.

(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Street Railway Review*, Chicago, 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.

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The Reinforced-Concrete Bridge at Trinidad, Col.* (14) Feb. 10.
Plate Girder Spans on the Chicago, Burlington & Quincy R. R.* (14) Feb. 17.
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The Pollasky Reinforced Concrete Bridge.* (14) Feb. 24.
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Rapid Plate Girder Erection with a Derrick Car. (14) Mar. 3.
Construction Methods at the Stone Bridge at Hartford, Conn.* (14) Mar. 3.
Excavating and Concreting the New York Anchorage of the Manhattan Bridge.* (14) Mar. 3.
The Wabash River Bridge at Terre Haute, Indiana.* Malverd A. Howe, M. Am. Soc. C. E. (13) Mar. 8.
Calcul des Ponts Courbes. M. Résal. (43) 4e Trimestre, 1905.
Note sur un Système de Pont à Arc en Charpente et à Tirants Métalliques.* M. Thiollière. (43) 4e Trimestre, 1905.
Pont a Transbordeur sur le Port-Vieux à Marseille.* G. Leinekugel Le Cocq. (33) Serial beginning Feb. 24.
Gewölbegürten für Grosse Lasten.* Rudolph Heim. (78) Feb.

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Lightning Protection.* J. V. E. Titus. (Paper read before the Ohio Interurban Ry. Assoc. and the Cent. Elec. Ry. Assoc.) (72) Feb.
The Economy of Combined Railway and Lighting Plants. Ernest Gonzenbach. (Paper read before the Northwestern Elec. Assoc.) (72) Feb.

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Hydro-Electric Plant at Montereale.* (12) Feb. 9.
A Contribution to the Theory of the Single-Phase Induction Motor.* Val. A. Fynn. (26) Serial beginning Feb. 9.
The Chesterfield Electricity and Tramway Undertakings.* (26) Feb. 9.
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Modern Underground Construction (for Electric Lighting and Power). W. D. Burford. (Abstract of Paper read before the Northwestern Elec. Assoc.) (27) Feb. 10.
The Cooper-Hewitt Single-Phase Converter.* (27) Feb. 10.
The Mansfield Electrical Undertaking.* (26) Feb. 16.
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The Carbon Regulator for Automatic Booster Control.* (73) Feb. 16.
Mercury Arc Rectifier for Charging Storage Batteries.* (46) Feb. 17.
The Burlington, Vt., Municipal Electric Plant.* (27) Feb. 17.
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Phasemeters and Their Calibration. W. E. Sumpner. (73) Feb. 23.
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The District Supply System of the North Shore Electric Company, near Chicago.* (27) Feb. 24.
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Determination of Feeder-Drop. J. E. Wallace. (17) Mar. 3.
The Design of a Small Electric Power Station. James F. Hobart. (27) Serial beginning Mar. 3.
The Slide Rule as a Substitute for the Wire Table. Carl P. Nachod. (27) Mar. 3.
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Residence Wiring.* Louis J. Auerbacher. (27) Mar. 3.
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L'Usine Hydro-Electrique d'Entraygues et la Distribution d'Energie Electrique dans la Région de Toulon.* P. Caufourier. (33) Feb. 3.

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Some Notes on Fuel Briquetting in America. Clarence M. Barber. (1) Jan.
Report of a Test on a Portland Cement Plant.* E. C. Soper. (4) Feb.
The Prime Mover of the Future.* C. E. Sargent. (4) Feb.
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Tests of Small Compressors.* Max Kurth. (45) Feb.
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The Conditions of Mechanical Draught Production. Walter B. Snow. (10) Mar.
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The East Jersey Pipe Co.'s Lock-Bar Pipe Plant. (14) Mar. 3.
Boiler Efficiency Tests. George T. Hanchett. (27) Mar. 3.
Gas Producers for Power. Julius Wile. (From Paper read before the Technology Club.) (20) Mar. 8.
Molding Sands. H. E. Field. (62) Mar. 8.
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Gusseiserne Muffenrohrverbindungen.* Gustav Simon. (50) Feb.
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The Use of Vanadium in Metallurgy. Léon Guillet. (71) Vol. 68.
Steel Used for Motor Car Construction in France.* Léon Guillet. (71) Vol. 68.
Segregation in Steel Ingots.* B. Talbot. (71) Vol. 68.
The Reversible and Irreversible Transformations of Nickel Steel. L. Dumas. (71) Vol. 68.
The Nature of Troostite.* Carl Benedicks. (71) Vol. 68.
Note on the Occurrence of Copper, Cobalt, and Nickel in American Pig Irons. Edward Demille Campbell. (71) Vol. 68.
The Influence of Nickel and Carbon on Iron. G. B. Waterhouse. (Dissertation in partial fulfilment of requirements for degree of Ph.D., Columbia Univ.) (71) Vol. 68.
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The Talbot Continuous Steel Process and Its Benefits in Steel-Making. G. A. Wilson. (Paper read before the West of Scotland Iron and Steel Inst.) (22) Feb. 16; (62) Mar. 1.
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* Illustrated.

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* Illustrated.

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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## THE SCRANTON TUNNEL OF THE LACKAWANNA AND WYOMING VALLEY RAILROAD.*

By George B. Francis and W. F. Dennis, Members, Am. Soc. C. E.

To be Presented May 16th, 1906.

During the years 1901, 1902 and 1903, Westinghouse, Church, Kerr and Company constructed a double-track, high-speed, electric railroad, on private right of way, in the heart of the Northern Anthracite coal field, with termini at Wilkes-Barre on the south, and Scranton on the north, a distance of about 20 miles.

The entrance to Scranton was over the hill on the southerly side of the city, with 4% grades, on a temporary line built to permit an early opening of the road.

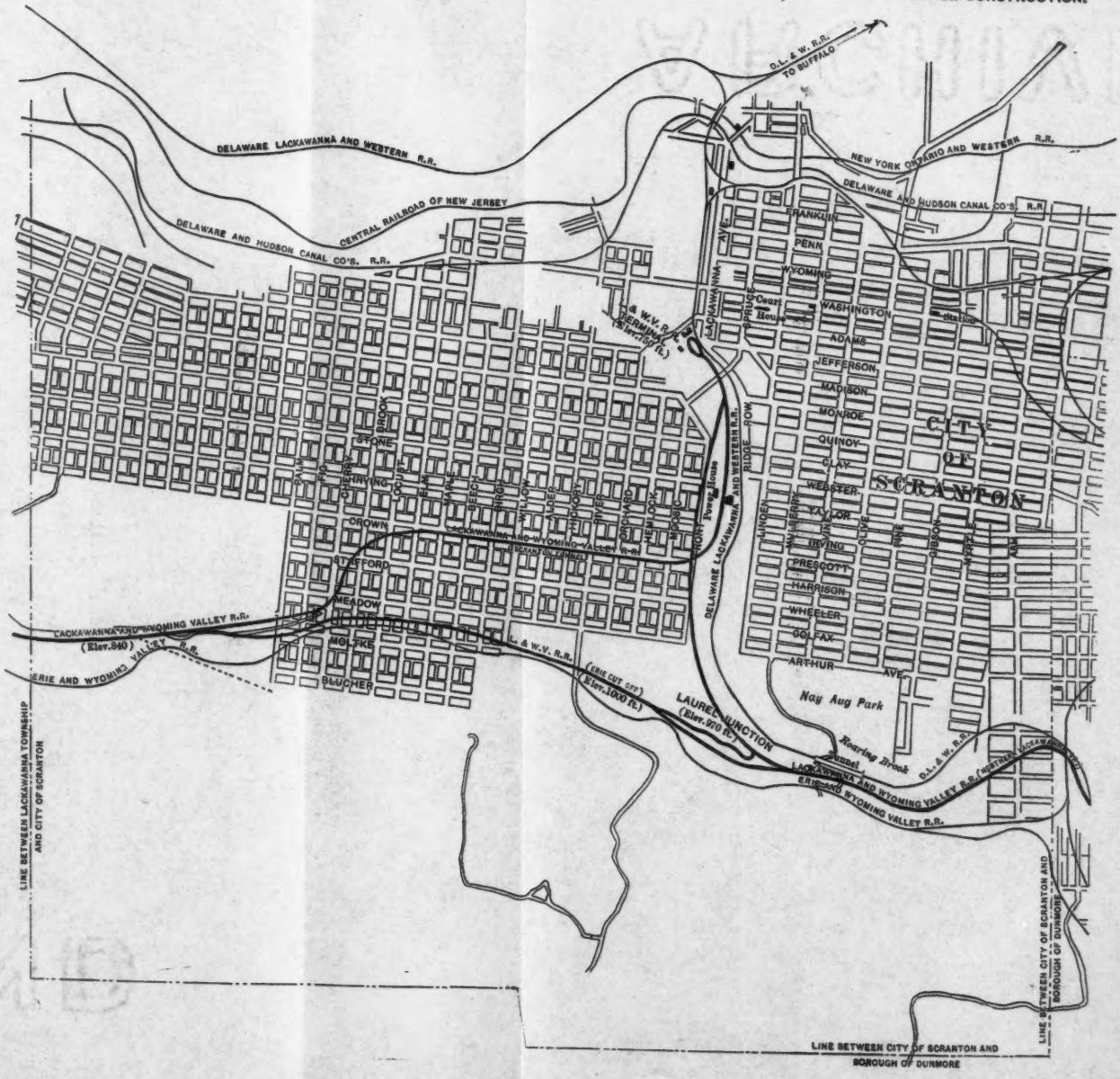
During 1904 and 1905 a tunnel was constructed through this hill, on a permanent line and at moderate grades. The object of this paper is to describe the construction of this tunnel, which was accomplished in record time, and which contained some interesting engineering features.

The preliminary surveys for the tunnel line were made in 1902, and the first location was under Irving Avenue, Scranton, one block nearer the center of the city than the existing line, the object being

*That portion of the paper describing the tunnel generally has been prepared by Mr. Francis, Civil Engineer for Westinghouse, Church, Kerr & Company, and that portion describing the contractor's plant and operations has been prepared by Mr. Dennis, Vice-President of the Rinehart & Dennis Company, General Contractors.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

PLATE XVI.
PAPERS, AM. SOC. C. E.
MARCH, 1906.
FRANCIS AND DENNIS ON
TUNNEL CONSTRUCTION.



to take advantage of the extensive old mine workings, known as the Dunmore No. 3 coal vein, cropping out just beyond the company's power plant. It was hoped that this might prove an easy, quick and inexpensive means of tunneling, but surveys in the mines demonstrated that the workings were not favorable to the accomplishment of this plan. The drift was above and below the tunnel grade and crossed the profile twice, introducing puzzling questions of support.

It was finally determined to locate a line which would avoid these old mine workings and clear the limits of the coal yet to be mined. The new line was located to the south of Irving Avenue, under private land contiguous to Crown Avenue.

The contract for a single-track tunnel was executed on June 1st, 1904, with the Rinehart and Dennis Company, of Washington, D. C. Time was the essence of this contract, which provided for the completion of the work, to a stage admitting of track laying throughout, in a period of 16 months, under a penalty and bonus clause providing for the payment of $200 per day.

Work was commenced on July 5th, 1904, after a brief delay on account of right-of-way matters. The first round of holes for the heading was fired on August 12th, 1904, at the north portal, about one month being consumed in excavating the approach cut. The excavation was completed and the tunnel ready for laying track on July 18th, 1905, the contractors earning a bonus of $19 000.

From a knowledge of the geology in the vicinity, and a determination of the nature of the rock through which the tunnel would be driven, it was evident that some portions would require lining; but, at the time the work was let, it was not known how much.

Typical sections were prepared showing the method of treatment of expected conditions.

After the work had progressed for a period of six months it was quite evident that nearly all the tunnel was in rock of inferior quality, and would require lining of some character for nearly its entire length. The rock had a tendency to slab off or drop in small pieces rather than settle down on the supports in large masses.

To effect a saving in the initial cost of construction, it was determined to introduce some form of permanent timber lining which would take the place of the more expensive masonry section. Instead of placing the timber outside of a future masonry section, it was put in the position of the masonry section, thus effecting a con-

siderable saving, both in excavation and masonry. At such future time as it is desired to reline the tunnel, short stretches of the timber may be removed and replaced with timber or masonry.

The dimensions of the tunnel are as follows:

| | | |
|---|---|---|
| Total length, face to face of portal masonry. | 4 747 | ft. |
| Total length excavated as tunnel..... | 4 640 | " |
| Portal masonry extended at north end.... | 16 | " |
| *Portal masonry extended at south end.... | 91 | " |
| Width, in clear, inside..... | 17 | " |
| Height above top of rail..... | 20 | " |
| Depth below top of rail..... | 2 | " |
| Arch, semi-circular, radius..... | 8.5 | " |
| Shaft No. 1, 10 by 20 ft., depth..... | 104 | " |
| Shaft No. 2, 10 by 20 ft., depth..... | 180 | " |

*Surveying.*—The alignment of the Scranton Tunnel presented some of the difficulties usually attendant on work of this character; the principal ones were:

1.—The center line of the tunnel at the surface passed through a great many buildings;

2.—There was no higher ground in the vicinity on the axis of tunnel;

3.—The surface was quite uneven, and five permanent points had to be established on the prime base line on Crown Avenue;

4.—Owing to the configuration of the surface at the portals, curves had to be extended into each end of the tunnel;

5.—The shafts were located to one side of the center line of the tunnel, and came partly without and partly within the tunnel prism.

A prime base was established along Crown Avenue, 45 ft. from, and parallel with, the projected tunnel line. This line was run and re-run, reversing the transit telescope, differences were eliminated and adjusted, and permanent points established. Then, as a check on the work, a line was run over the work several times, using no back-sights.

After a base line with no apparent error had been established in Crown Avenue, tangents were brought ahead from the existing tracks at each end to an intersection with this base line; and, at

* Extended to carry the roadway over the tunnel.



FIG. 1.—NORTH APPROACH, SCRANTON TUNNEL. TUNNEL LINE ON LEFT, TEMPORARY LINE ON RIGHT.

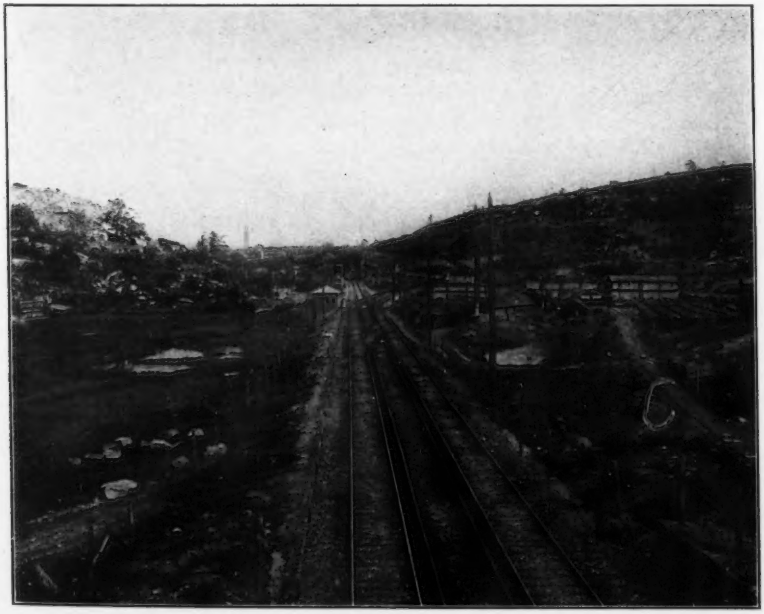


FIG. 2.—SOUTH APPROACH, SCRANTON TUNNEL.

the north end, a base 80 ft. long was obtained for measuring angles. Angles were turned a sufficient number of times to insure their correct valuation, and curves were run in and checked by direct measurements from tangents and by complete triangles, in which all distances and all angles were measured. These triangles were remeasured and adjusted until no appreciable error remained. By this method a permanent point was established on the center line of the curve at a convenient place near each portal.

From the points established along Crown Avenue, other points convenient to the shafts were put in place, and from these and at right angles thereto, monuments were established about 51 ft. away to take the line down the shafts. As the center line of the tunnel was 45 ft. distant, another offset was necessary at the foot of the shafts. It was complicated still further at these points, in the early stages of the work, by the presence of pillars or shoulders of rock left on either side at the bottom of the shafts for the protection of the hoisting apparatus, and two more offsets had to be made to get to the center line. After the removal of this rock the line was taken directly from the wires in the shafts by producing the lines about 200 ft. either way and repeating the operations until there was no appreciable error.

The method of taking the line into the shafts, as shown in Fig. 1, was simple, but great care was taken to make the lines accurate. An observer with a transit, with a fixed fore-sight, was always left on the surface of the ground. Plumb-bobs, weighing about 30 lb., were suspended with copper wires from points about 2 ft. above the curb, or top, of the lining of the shaft.

The wires were hung over a notched bolt, running through a U-shaped piece of iron, with a thumb-screw and spring adjustment. The plumb-bobs were steadied in casks of water or oil at the bottom of the shafts, and the casks had covers so that dripping water would not disturb the surface of the liquid. Even with this precaution, there was always some tremor in the wires, owing to the fact that they were frequently struck by falling water.

The lines met in the headings between the south portal and Shaft No. 1 with a variation of 0.16 ft.; between Shafts Nos. 1 and 2 with a variation of 0.02 ft.; and between Shaft No. 2 and the north portal with a variation of 0.23 ft. In no case was the center line, as run from the shafts, more than 1⅞ in. from the actual center line.

The grades met between the south portal and Shaft No. 1 with a variation of 0.02 ft.; between Shafts Nos. 1 and 2 with a variation of 0.07 ft.; and between Shaft No. 2 and the north portal with a variation of 0.05 ft.

*Alignment and Grade.*—At the south end of the tunnel a 4° 14′ curve, with a spiral 218.75 ft. long, was run in to connect the center line of the existing track with the center line of the tunnel. All the spiral and 270.34 ft. of regular 4° 14′ curve was inside the tunnel portal, or a total of 489.09 ft. of curve, was run in at this end.

At the north end, owing to a very narrow valley, a 10° curve, with spirals 400 ft. long, at each end, had to be introduced. One spiral, together with 186.21 ft. of regular 10° curve, or a total of 586.21 ft. of curve, was inside the tunnel portal.

At this end, as at the south portal, lines were given as the work progressed, so that the excavation for the heading was taken out to the full tunnel section.

The tunnel, generally, has a grade of 1%, but, for a short distance, at the north end it is 0.8 per cent.

*Excavation.*—The excavation was carried on at six different points of attack, two shafts being sunk, about 1 500 ft. apart, from which headings were worked in both directions, as well as at the north and south portals. Fig. 2 shows that 56%, or more than one-half, the tunnel excavation was removed through these shafts, the work being expedited thereby fully a year in time.

The method of tunneling was in accordance with the usual American practice. The top heading was taken out to the full size of the section, 9 by 21 ft., and the length carried on in advance of the bench varied from 50 to 800 ft. The bench was afterward split in two lifts.

The quantity of excavation per linear foot of tunnel was as follows:

| | Rock Section. Cu. Yd. | Masonry Section. Cu. Yd. | Timber Section. Cu. Yd. |
|---|---|---|---|
| Headings | 4.71 | 7.04 | 8.38 |
| Benches | 9.00 | 11.00 | 12.00 |
| Totals | 13.71 | 18.04 | 20.38 |
| Falling beyond payment line | 1.00 | 1.13 | 1.18 |

## METHOD OF TRANSFERRING THE CENTER LINE DOWN A SHAFT.

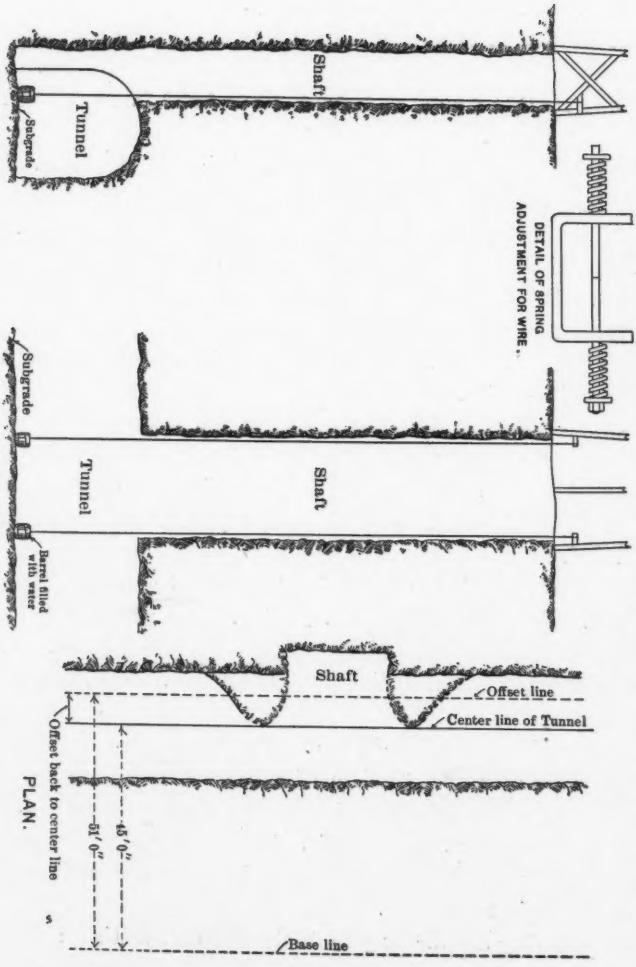



Fig. 1.

*Disposal of Spoil.*—The portal excavation at the north end was dumped along the bank of Roaring Brook. At the south end the greater portion was loaded on cars and used as rip-rap at a point on the line of the road nearly 16 miles away.

The excavation from Shaft No. 1 was dumped on low land near by, purchased for the purpose; and that from Shaft No. 2 was hauled by surface incline to a dump about 1 200 ft. away and from 50 to 60 ft. higher.

The work was carried on by night and day in two 10-hr. shifts.

*Lining.*—A small quantity of temporary lining, outside of the masonry section, was required at each portal and at Shaft No. 1, at which points there was danger of immediate and frequent falls from the roof. At other places these falls were less frequent, but the roof would slab off to such an extent as to make it necessary to line, either with timber or masonry, before beginning the operation of regular train service.

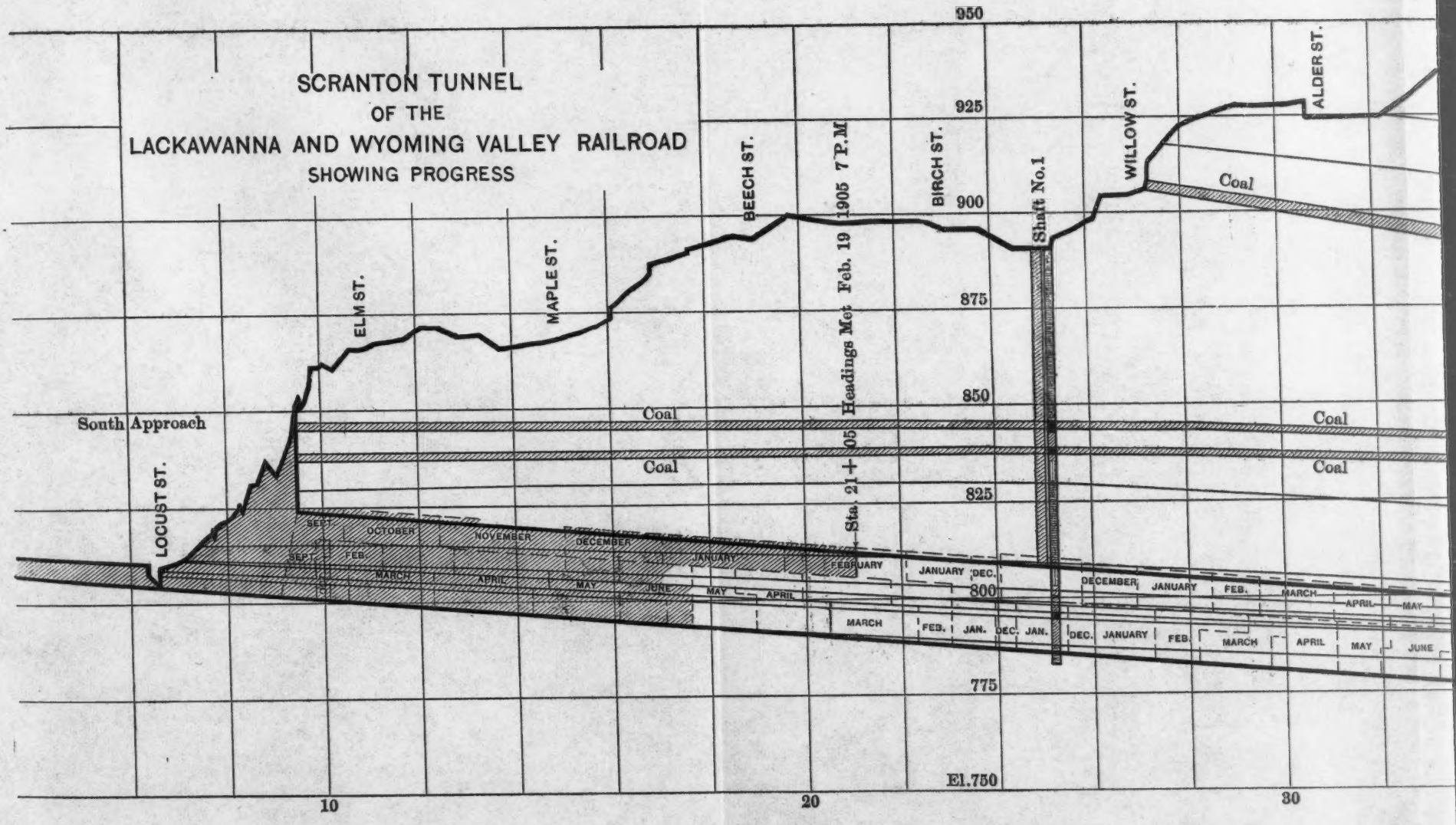
Concrete masonry lining was adopted for those portions of the tunnel near the portals and near the shafts, where the rock was of the poorest quality. Lining of this kind, being the most expensive, was restricted as much as possible, and permanent timber lining substituted.

The permanent timber lining is of the usual pattern of voussoir ribs, 5 ft. on centers, with a 4-in. lagging. The yellow pine timber used for this purpose should last about 12 years before requiring renewal, and at the end of that time it can be renewed or replaced with masonry.

At three different points in the tunnel there were a few hundred feet where the rock was found sufficiently good to require no lining. There has been one fall, of moderate size, however, since the opening of the tunnel for regular traffic. These portions of the roof are being carefully watched, and if there is much uncertainty as to falls it will have to be lined.

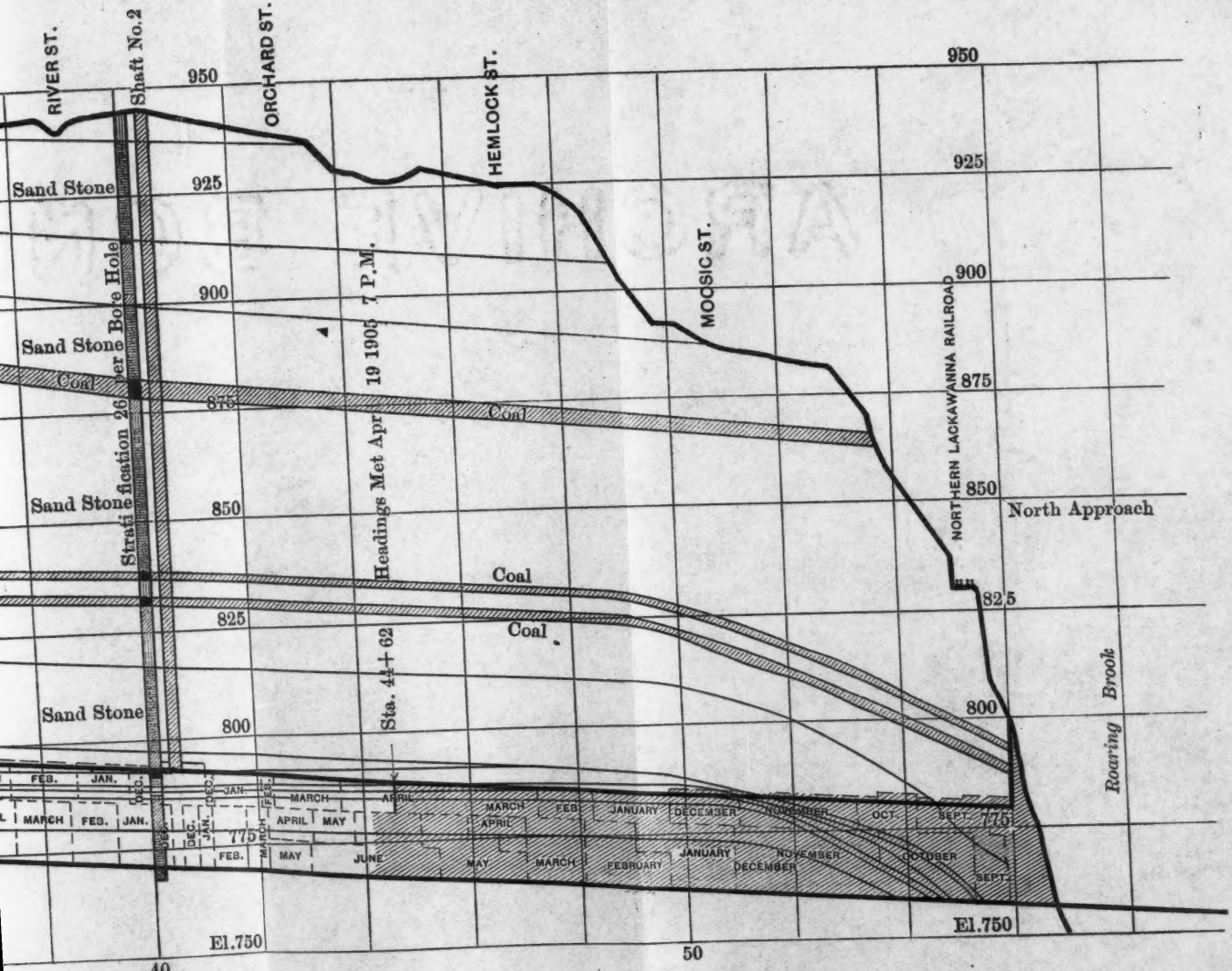
The following are the lengths of the different sections:

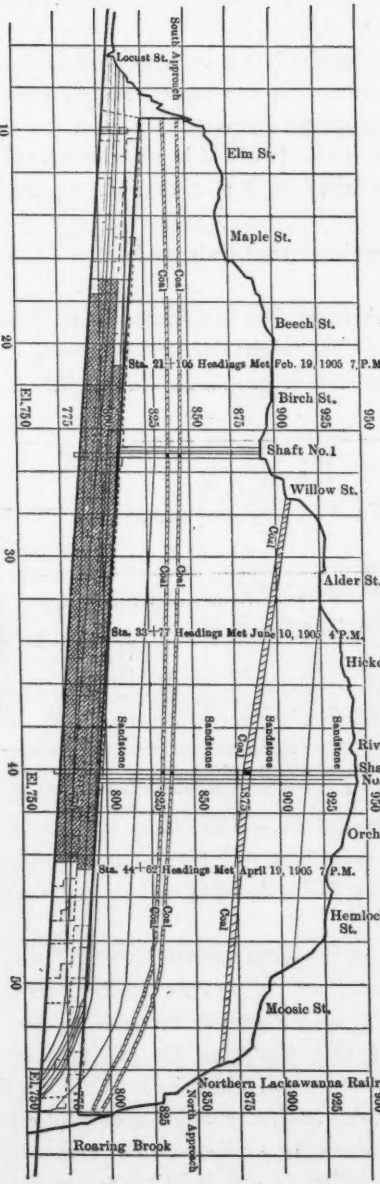
| | |
|---|---|
| Plain rock section | 1 305 ft. |
| Timber-lined section | 2 717 " |
| Masonry section | 725 " |
| Total | 4 747 " |


SCRANTON TUNNEL
OF THE
LACKAWANNA AND WYOMING VALLEY RAILROAD
SHOWING PROGRESS
950
925
900
875
850
825
800
775
El.750
LOCUST ST.
ELM ST.
MAPLE ST.
BEECH ST.
BIRCH ST.
WILLOW ST.
ALDER ST.
Shaft No.1
Headings Met Feb. 19 1905 7 P.M
Sta. 21+05
South Approach
Coal
Coal
Coal
Coal
SEPT
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUG
10
20
30

950
925
900
875
850
825
800
775
El.750
BIRCH ST.
Shaft No.1
WILLOW ST.
ALDER ST.
HICKORY ST.
RIVER ST.
Coal
Coal
Coal
Sand Ston
Sand Ston
Sand Ston
Sand Ston
Headings Met June 10 1905 4 P.M.
Sta. 33+77
JANUARY
DEC.
DECEMBER
JANUARY
FEB.
MARCH
APRIL
MAY
JUNE
JULY
FEB.
JAN.
DEC.
JAN.
DEC.
JANUARY
FEB.
MARCH
APRIL
MAY
JUNE
JUNE
MAY
APRIL
MARCH
FEB.
JAN.

PLATE XVIII.
PAPERS, AM. SOC. C. E.
MARCH, 1906.
FRANCIS AND DENNIS ON
TUNNEL CONSTRUCTION.






SCRANTON TUNNEL: PROPORTION OF MATERIAL TAKEN OUT AT SHAFTS AND PORTALS.

Shaft No. 1.---- = 29 265 cu. yd.
" " 2.---- = 20 090 " "
Total by shafts = 49 355 " "
" " portals = 38 105 " "
" Excavation = 87 460 " "
56 % taken out through shafts.

FIG. 2.

The proportions of concrete mixture for the two classes specified were as follows:

Class "A" concrete, in the arches of the roof or in the side walls where the thickness does not exceed 26 in., 1 part cement, 2 parts sand and 4 parts broken stone.

Class "B" concrete, in the side walls or tunnel arches, where the backing is rock in place, 1 part cement, 3 parts sand and 5 parts broken stone.

Table 1 gives the cement tests made.

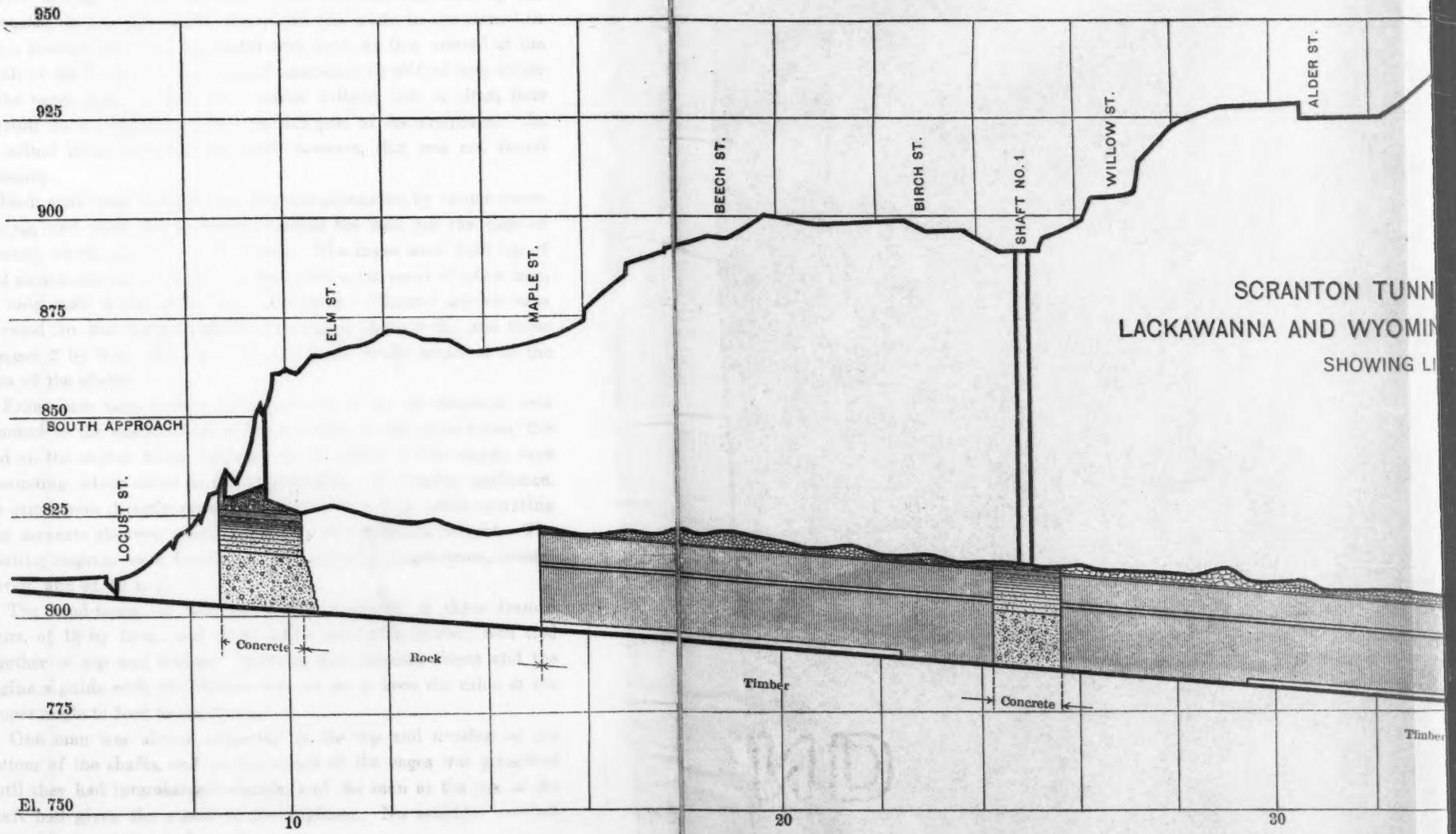
TABLE 1.—AVERAGE TENSILE STRENGTH OF BRIQUETTES TESTED.
Lehigh Portland Cement.

| CONSIGNMENT. | | Briquettes made. | FINENESS. | | Boiling Test. | MIXTURE. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Neat, 20% Water. | | | 1 Cement, 3 Sand, 10% Water. | |
| Car No. | No. of Barrels. | | 100 mesh. | 200 mesh. | | 1 day. | 7 days. | 28 days. | 7 days. | 28 days. |
| L. V. 68 119 | 150 | 6 | ..... | ..... | ..... | ..... | ..... | ..... | 308 | 400 |
| L. V. 5 379 | 150 | 18 | 89 | 72 | N. G. | 293 | 709 | 857 | ..... | |
| L. V. 71 827 | 150 | 30 | 87 | 69 | O. K. | 211 | 687 | 795 | 267 | ..... |
| L. V. 64 005 | 150 | 30 | 90 | 75 | O. K. | 269 | 739 | 800 | 337 | 418 |
| L. V. 70 298 | 150 | 30 | 90 | 73 | O. K. | 168 | 765 | 842 | 246 | 487 |
| L. V. 64 198 | 150 | 30 | 90 | 73 | O. K. | 271 | 724 | 851 | 250 | 393 |
| L. V. 61 662 | 150 | 30 | 90 | 72 | ..... | 264 | 687 | 796 | 234 | 337 |
| D. L. & W. 33 082 | 150 | 30 | 90 | 72 | O. K. | 301 | 742 | 854 | 300 | 330 |
| D. L. & W. 26 354 | 150 | 30 | 90 | 70 | O. K. | 383 | 849 | 937 | 244 | 434 |
| | | | | | | | | | | 373 |

NOTE.—With the exception of the first item, the number of briquettes tested in each instance was six, and the figures given herein are the averages of the various tests.

*Shafts.*—There are two shafts (10 by 20 ft. neat size), which were located at available points, and divided the tunnel into three nearly equal parts. Shaft No. 1 has a depth of 104 ft. and Shaft No. 2 a depth of 180 ft.

These shafts were placed to one side of the center line of the tunnel, the object being to provide a place where the shaft leads and rigging would be out of the way and be less likely to be injured by blasting, thus obviating the resultant delays in the early prosecution of the work at these points. This location of the shafts was also a safeguard against possible accidents caused by dropping tools, etc., from above, or spoil from the cars while being hoisted. As a further protection to this hoisting apparatus against blasting,




SCRANTON TUNN
LACKAWANNA AND WYOMIN
SHOWING LI

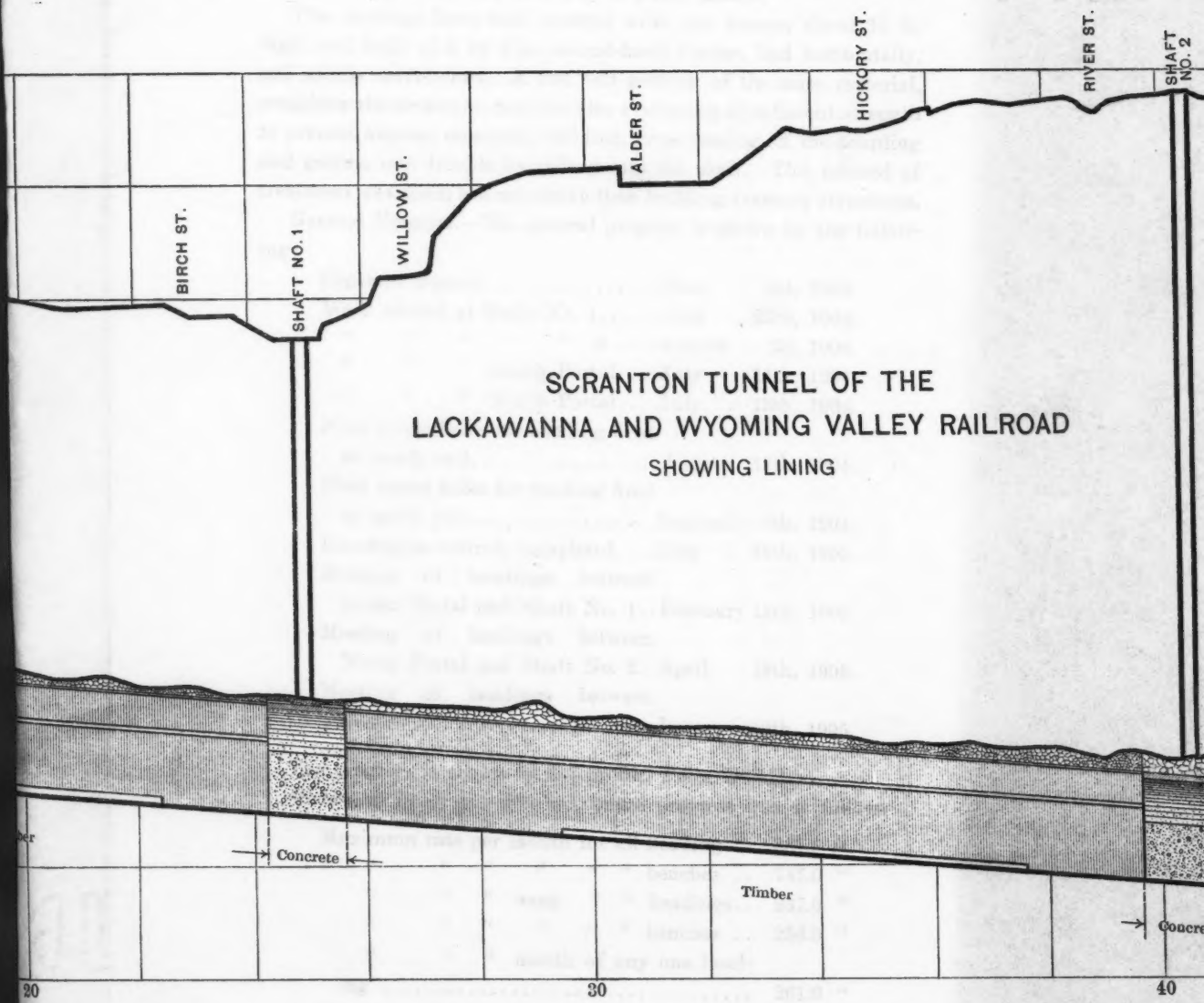
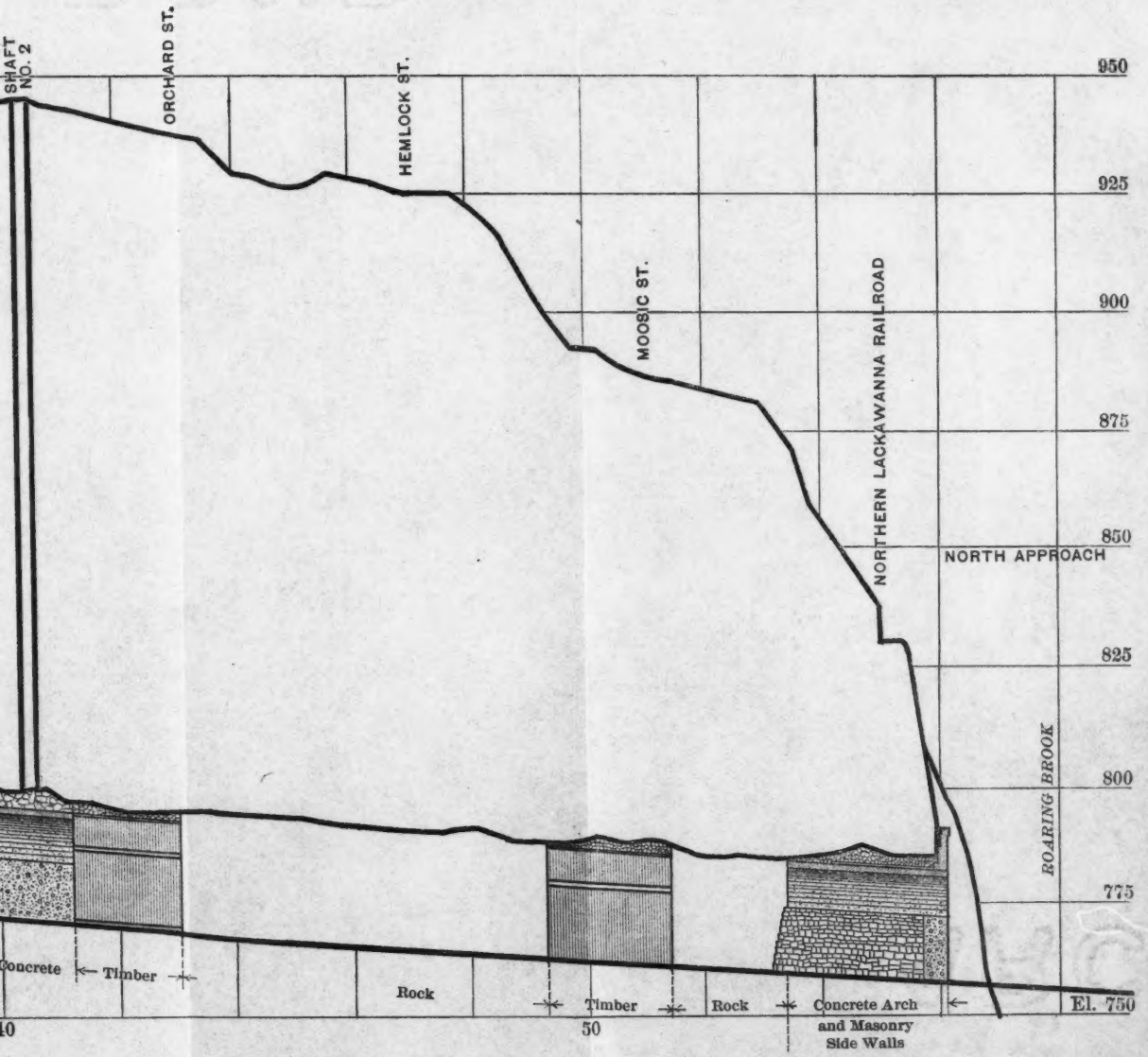

BIRCH ST.
SHAFT NO. 1
WILLOW ST.
ALDER ST.
HICKORY ST.
RIVER ST.
SHAFT NO. 2
SCRANTON TUNNEL OF THE
LACKAWANNA AND WYOMING VALLEY RAILROAD
SHOWING LINING
Concrete
Timber
20
30
40

PLATE XIX.
PAPERS, AM. SOC. C.E.
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TUNNEL CONSTRUCTION.



two shoulders were left on either side of the shafts, and this rock was not removed until the tunnel excavation had advanced to points where the shaft rigging was safe from the effects of blasting.

This arrangement of the shafts was specially requested by the contractor, as it would enable him to lay the tracks in the tunnel in such a manner that the cars loaded with spoil, as they arrived at the mouth of the shafts, could, if found necessary, be shifted into either of the cages and raised to the surface without loss of time, thus securing the maximum service from this part of the equipment. In the actual prosecution of the work, however, this was not found necessary.

Each shaft was divided into two compartments by center cross-bracing, and these compartments formed the well for the cage or elevator, which was 8 ft. 7 in. square. The cages were built up of steel shapes, strongly riveted together, with a top cover of plate iron, the only wood about them being the floors. Channel guides were provided for the entire height of the cages, about 9 ft., and these engaged 5 by 8-in., dressed, hard-pine leads firmly attached to the sides of the shafts.

From each cage a wire hoisting cable, $\frac{7}{8}$ in. in diameter, was attached to the engine, both cables winding on the same drum, the load on the engine being lightened to the extent of the empty cage descending, which acted as a counterweight. As a safety appliance, the cages were directly cross-connected with a $\frac{3}{4}$-in. cable operating over separate sheaves, which acted as a direct counterweight. The hoisting engines were horizontal, two-cylinder, single-drum, steam-driven, and of 40 h. p.

The head-house, or hoisting frame, consisted of three framed bents, of 12 by 12-in. and 12 by 14-in. hard-pine timber, well tied together at top and bottom. Between this hoisting frame and the engine a guide with two sheaves was set up to keep the cable at the proper angle to feed to the drum.

One man was always stationed at the top and another at the bottom of the shafts, and no movement of the cages was permitted until they had interchanged signals, and the man at the top of the shaft had given the signal to the engineer. No accident resulted from the use of the shafts and cages.

The two shafts have been left for ventilating purposes; the rock

sides, being fairly sound, will not cave in to any extent, even if the timber lining, which has been left in place, decays.

The openings have been covered with crib houses, about 10 ft. high, and built of 8 by 8-in. second-hand timber, laid horizontally, and solidly drift-bolted. A flat roof-grating, of the same material, completes the structure, and provides a covering of sufficient strength to prevent anyone, especially children, from tearing off the boarding and getting into trouble by falling into the shaft. This method of treatment was much less expensive than building masonry structures.

*General Progress.*—The general progress is shown by the following:

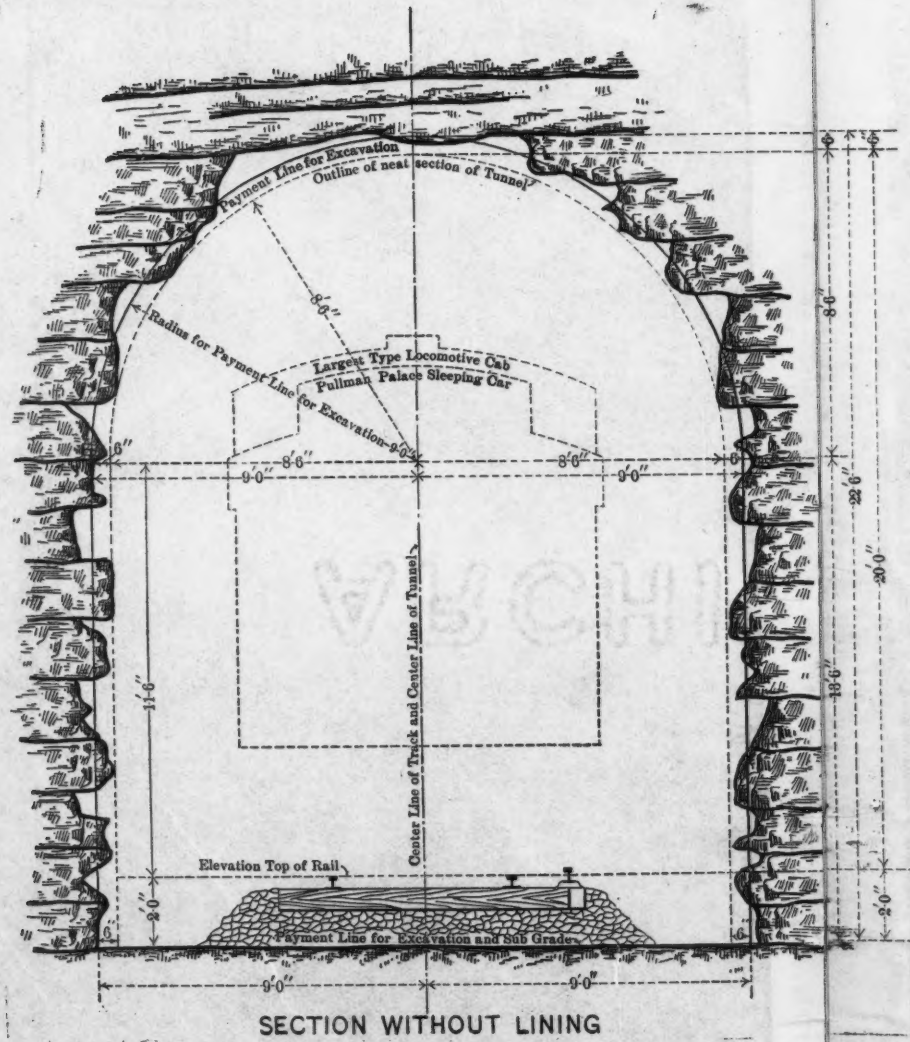
| | | |
|---|---|---|
| Contract signed | June | 1st, 1904. |
| Work started at Shaft No. 1 | July | 25th, 1904. |
| " " " " " 2 | August | 2d, 1904. |
| " " " South Portal | July | 11th, 1904. |
| " " " North Portal | July | 13th, 1904. |
| First round holes for heading fired at north end | August | 12th, 1904. |
| First round holes for heading fired at south end | September | 8th, 1904. |
| Excavation entirely completed | July | 18th, 1905. |
| Meeting of headings between South Portal and Shaft No. 1 | February | 19th, 1905. |
| Meeting of headings between North Portal and Shaft No. 2 | April | 19th, 1905. |
| Meeting of headings between shafts | June | 10th, 1905. |

The progress is shown by the profile, Plate XVIII.

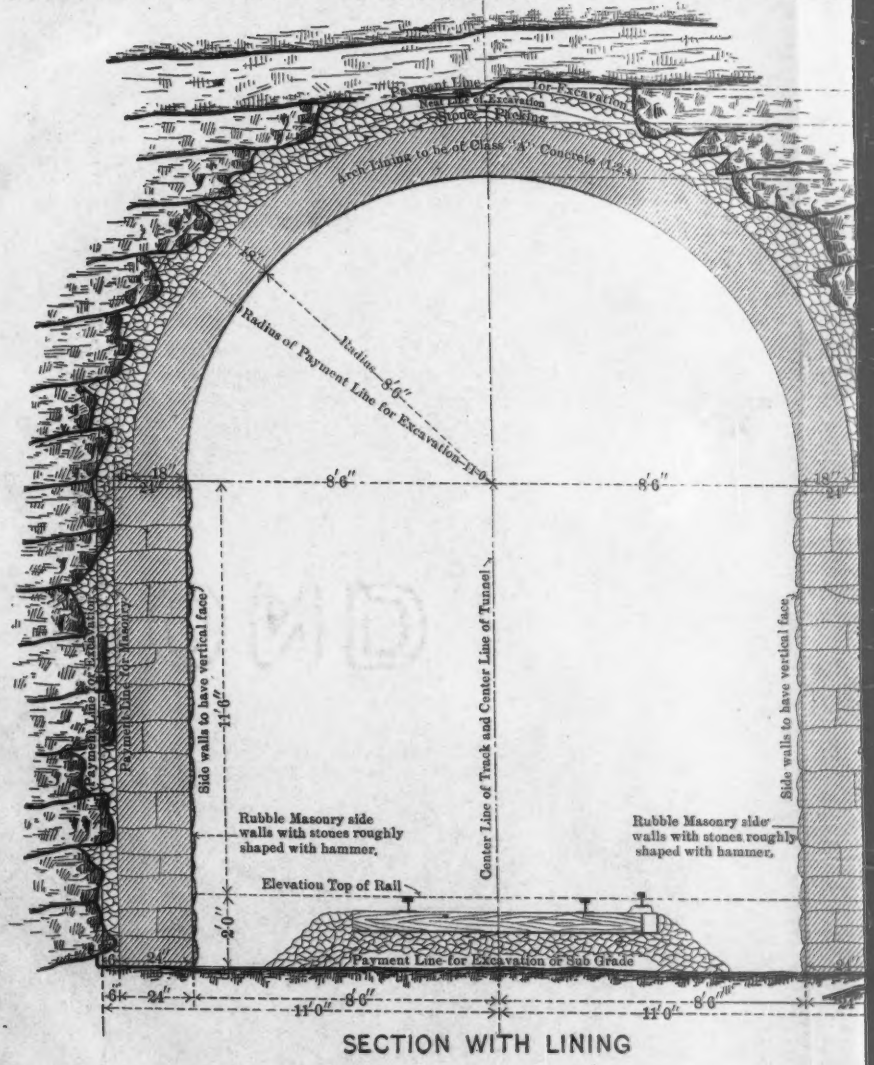
*Maximum Progress.*—The maximum progress was as follows:

| | |
|---|---|
| Maximum rate per month for all headings | 881.5 ft. |
| " " " " " " benches | 745.0 " |
| " " " week " " headings | 237.0 " |
| " " " " " " benches | 256.0 " |
| " " " month of any one heading | 261.0 " |
| Maximum rate per week of any one bench | 85.0 " |
| " " " month for shafts | 111.0 " |

# THE SCRANTON TUNNEL OF THE LACKAWANNA AND WYOMING VALLEY RAIL

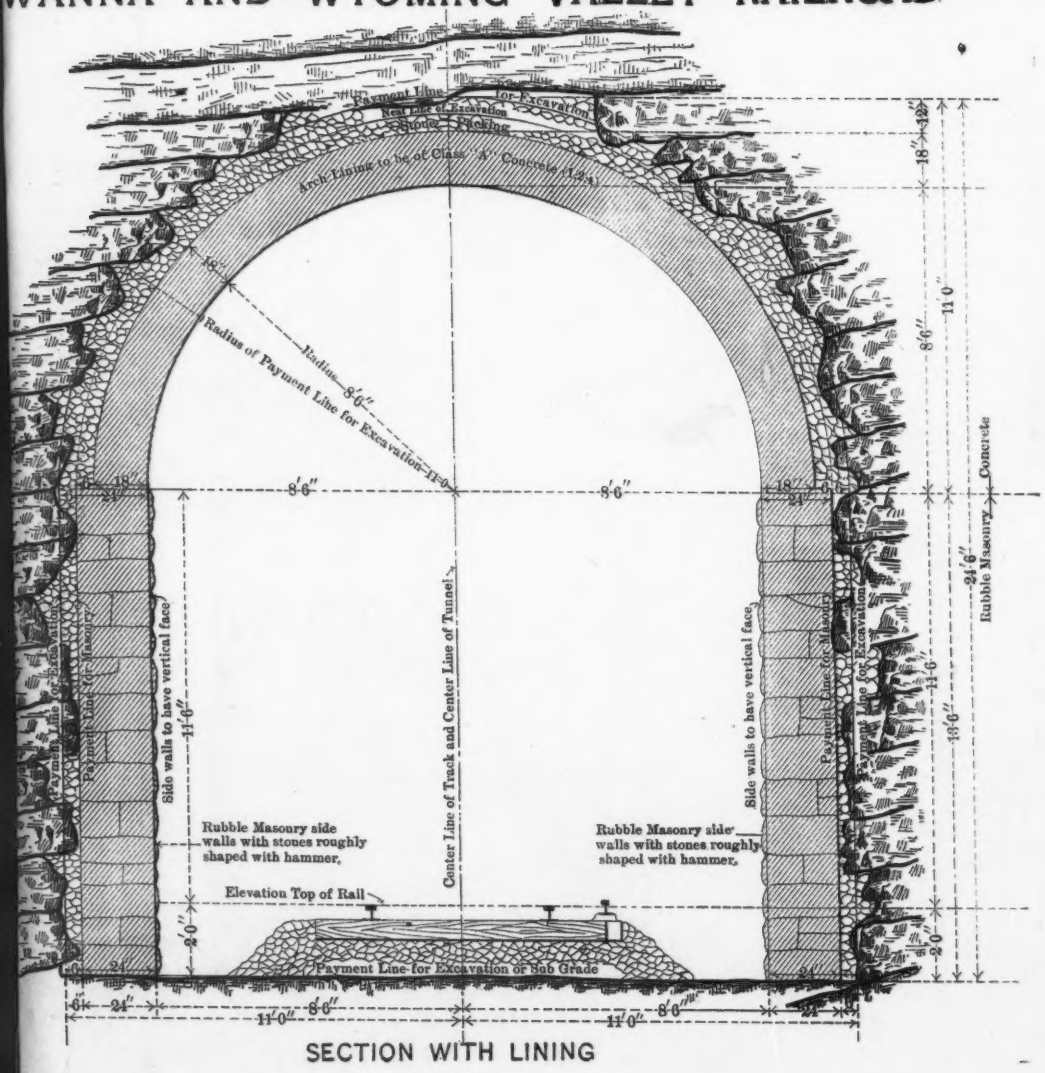



SECTION WITHOUT LINING

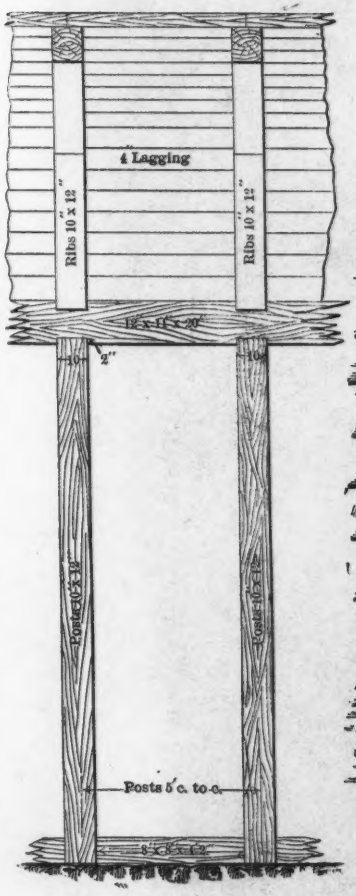


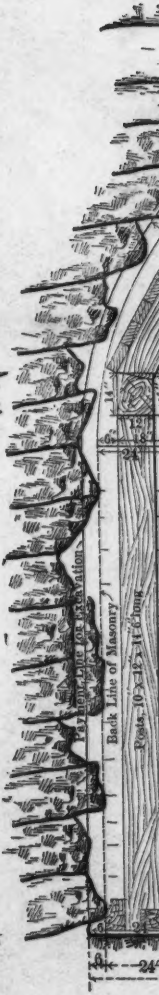

SECTION WITH LINING

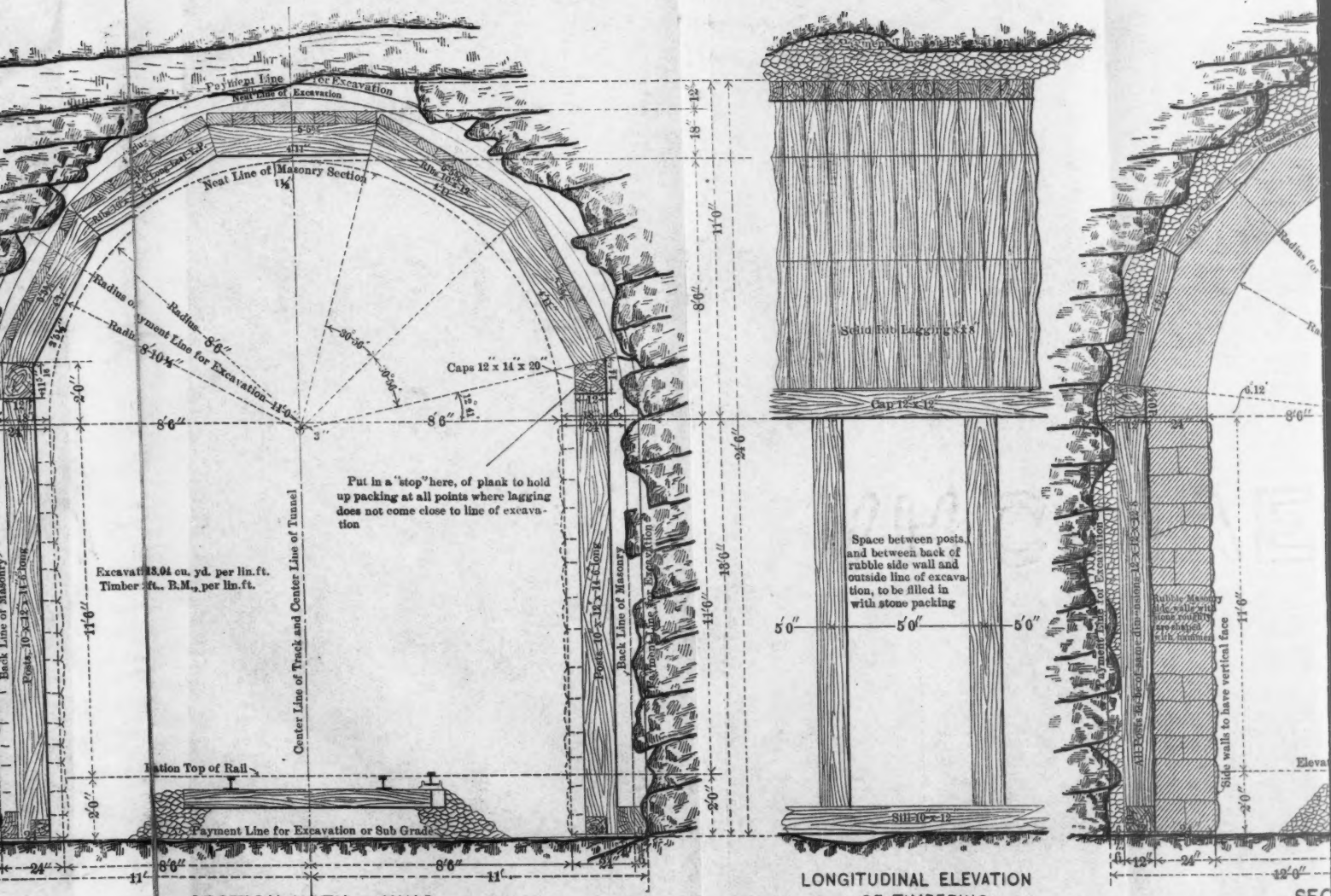
WANNA AND WYOMING VALLEY RAILROAD




SECTION WITH LINING



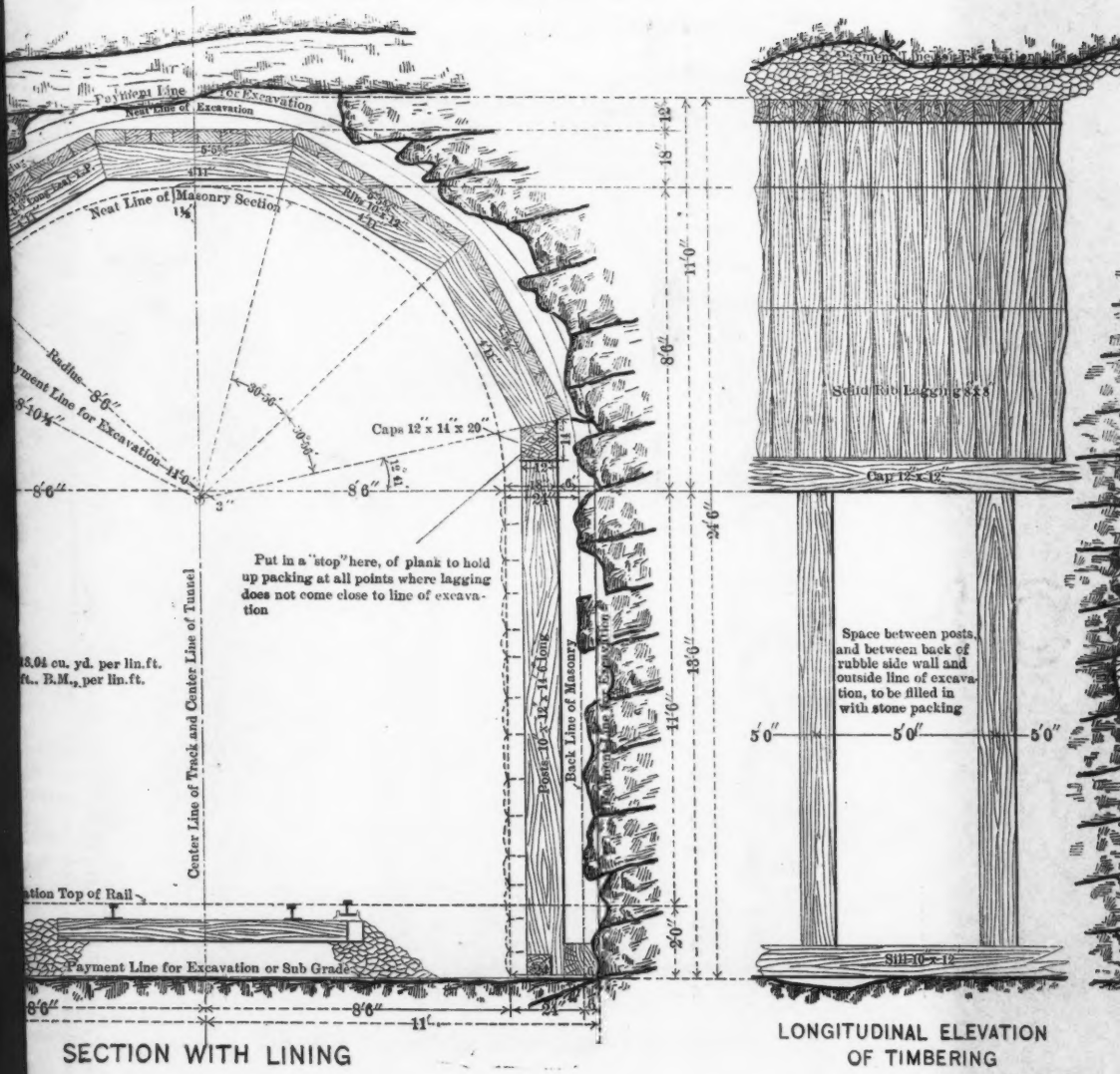






SECTION WITH LINING

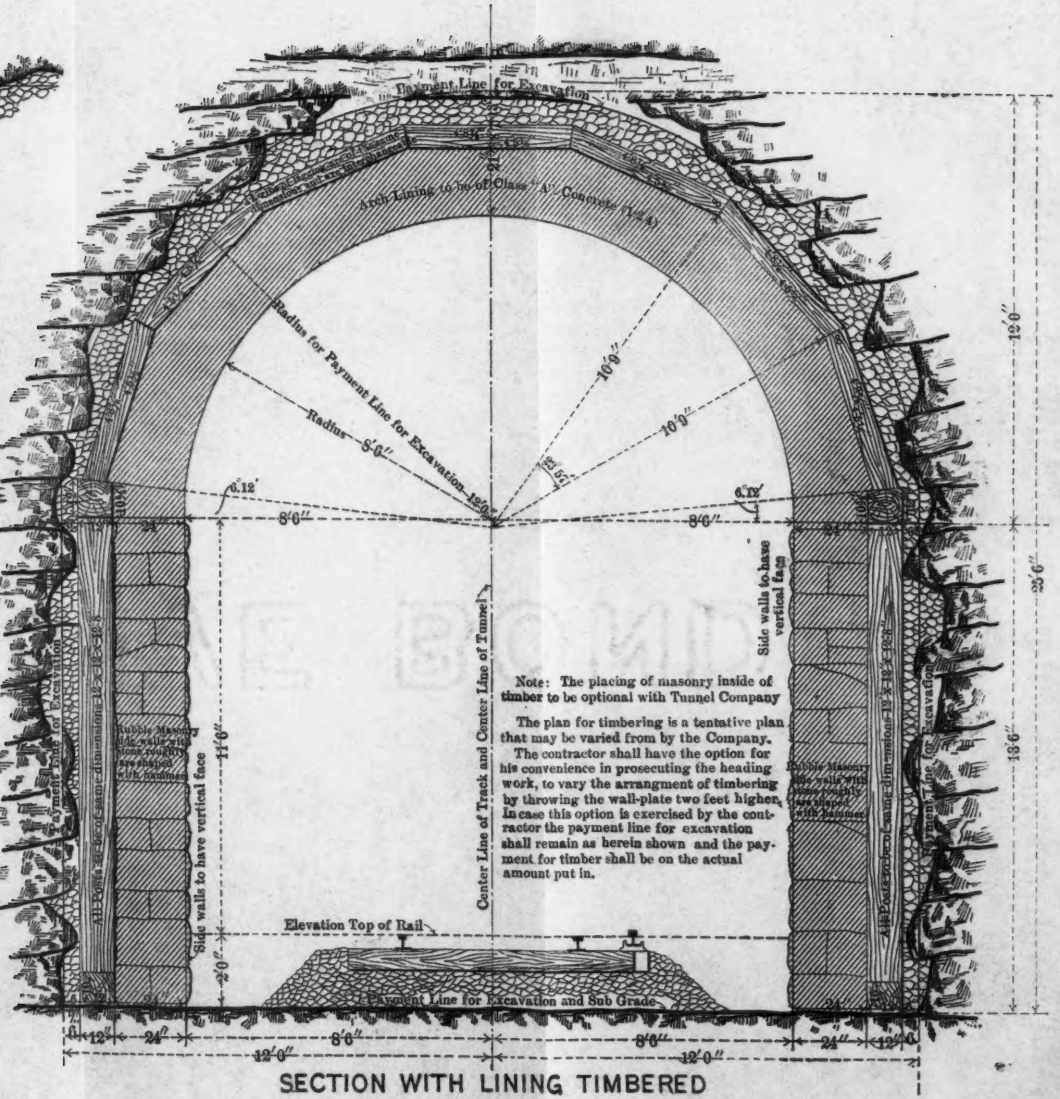
LONGITUDINAL ELEVATION OF TIMBERING

SEC




SECTION WITH LINING

LONGITUDINAL ELEVATION OF TIMBERING




SECTION WITH LINING TIMBERED

Table 2 shows the progress in detail.

*Lighting.*—The tunnel is lighted by electricity, 16-c. p. incandescent lamps being installed at intervals of approximately 40 ft. throughout. The lamps are arranged in groups, of six 110-volt lamps per group, all lamps of each group being in series between the third rail and the track rail, and are located as high as possible on one side of the tunnel walls. Every sixth lamp is connected to the rail circuit with a No. 4 Brown and Sharp bare copper wire, which is securely fastened to the nearest tie and to the side wall of the tunnel in such a manner as to be entirely clear of moving equipment and safe from disturbance by the track men.

There is one feeder wire, of the same polarity as the third rail, running from end to end of the tunnel, to which each group of lights is tapped at every sixth lamp. The connection from the last lamp of each group is run directly to the track.

The positive feeder is connected to the third rail through a single-pole, 500-volt, 25-ampere, quick-break, knife-switch, and one 25-ampere, open fuse, mounted on a 50-ampere D. & W. fuse-block, all enclosed in a water-proof, wooden box, at the north portal, by which control is had of all the lamps in the tunnel from a single convenient point.

A 500-volt, 3-ampere, porcelain, open-fuse cut-out, of D. & W. make, is placed in each tap between the feeder and the first lamp. This affords protection to each individual circuit, so that an accident, which would cause a short circuit of any one of the independent groups, would not throw the entire installation out of commission.

The cost of the installation was about $8 per light.

*Track.*—The double track, approaching the tunnel at either end, is gauntleted through the tunnel, and two third rails are provided for electric contact, thus making six rails in a single-track tunnel.

The track is of 90-lb., Am. Soc. C. E. section, for the running rail, laid with tie-plates; and of 75-lb., Am. Soc. C. E. section for the third rail, on standard ties and rock ballast, 1 ft. deep under the ties, all rails being properly bonded for the return circuit.

*Signals.*—The Union Switch and Signal Company's electric train-staff system of block signaling is in use, for the prevention of

TABLE 2.—MONTHLY PROGRESS ON SCRANTON TUNNEL, IN LINEAR FEET.

| DATE. | HEADINGS. | | | | | | BENCH. | | | | | | TOTALS. | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month of | South Portal. | Shaft No. 1. | | Shaft No. 2. | | North Portal. | South Portal. | Shaft No. 1. | | Shaft No 2. | | North Portal. | Heading. | Bench. | |
| | | South. | North. | South. | North. | | | South. | North. | South. | North. | | | | |
| July, 1904 | Started July 11. | ..... | ..... | ..... | ..... | Started July 13. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 9 + 56 to 55 + 96. |
| August | ..... | ..... | ..... | ..... | ..... | 41 | ..... | ..... | ..... | ..... | ..... | ..... | 41 | ..... | First round of holes fired Aug. 12. |
| September | 88 | ..... | ..... | ..... | ..... | 195 | 24 | ..... | ..... | ..... | ..... | 69 | 223 | 93 | |
| October | 194 | 75 | 63 | 33 | 30 | 104 | 30 | 10 | 10 | ..... | ..... | 131 | 499 | 181 | |
| November | 261 | 13 | 17 | 11 | 26 | 216 | ..... | 46 | 40 | 10 | 10 | 196 | 544 | 302 | |
| December | 201 | 59 | 116 | 39 | 16½ | 130 | ..... | 47 | 56 | 29 | 31 | 110 | 561½ | 273 | |
| January, 1905 | 254 | 140 | 156 | 97 | 92½ | 142 | ..... | 85 | 122 | 71 | 26 | 120 | 881½ | 424 | |
| February | 151 | 102 | 96 | 125 | 25 | 100 | 40 | 73 | 95 | 84 | 64 | 160 | 599 | 516 | |
| March | Met Feb. 19th | ..... | 158 | 103 | 126 | 124 | 175 | 164 | 149 | 105 | 45 | 107 | 511 | 745 | |
| April | ..... | ..... | 114 | 82 | 101 | 142 | 202 | 174 | 136 | 89 | 40 | 50 | 439 | 691 | |
| May | ..... | ..... | 93 | 103 | Met A | pr. 19th | 183 | 131 | 94 | 78 | 42 | 120 | 196 | 649 | |
| June | ..... | ..... | 70 | 75 | ..... | ..... | 100 | 27 | 124 | 106 | 87 | 143 | 145 | 587 | |
| July | ..... | ..... | Met Ju | ne 10th | ..... | ..... | ..... | 27 | 80 | 72 | ..... | ..... | ..... | 179 | |
| | | | | | | | 754 | 784 | 906 | 544 | 346 | 1 206 | 4 640 | 4 640 | |



FIG. 1.—SCRANTON TUNNEL; PLAIN ROCK SECTION.



FIG. 2.—SCRANTON TUNNEL; JUNCTION OF PLAIN ROCK SECTION AND CONCRETE-LINED SECTION.

collisions on this piece of single track, and thus trains are passed through with perfect safety.

*Costs.*—The following are the contract prices for the tunnel proper:

| | | |
|---|---|---|
| Shaft excavation | $7.00 | per cu. yd. |
| Tunnel excavation | 3.35 | " " |
| Backfilling over timber and behind masonry | 1.50 | " " |
| Overhaul, 100 ft. in excess of 1 000 ft. | 0.01 | " " |
| Class "A" concrete in forms | 9.00 | " " |
| Class "B" concrete in forms | 8.60 | " " |
| Third-class masonry | 6.50 | " " |
| Long-leaf yellow pine | 45.00 | " M., B. M. |

The average cost of the tunnel proper for excavation and lining, including the shafts, was $90 per linear foot.

*Engineers and Contractors.*—Westinghouse, Church, Kerr and Company, of New York, were the engineers for the work, and The Rinehart and Dennis Company, of Washington, D. C., were the contractors.

The execution of the work was under the personal supervision of Mr. P. B. Easterbrooks, Resident Engineer for Westinghouse, Church, Kerr and Company, and Mr. J. H. Rinehart, Second Vice-President and Secretary of The Rinehart and Dennis Company, to whom credit is due for its successful prosecution.

The purchase of the right of way, and the work of track laying, lighting and signaling were conducted by the operating department of the road, under the supervision of Mr. Charles F. Conn, Vice-President and General Manager.

*Contractor's Plant and Operations.*—Railroad delivery for coal, and a convenient water supply dictated the location of the air-compressor plant at the south end, and the compressor location fixed the situation of the camp, boarding houses and office.

The company's plans required two shafts, and the simultaneous excavation both ways from each shaft, and at the ends, thus making six points of simultaneous attack.

It was calculated that from 24 to 28 drills would be necessary,

and the requisite air supply was approximated at, roughly, 100 ft. per min. for each drill, at 100 lb. per sq. in., and the boiler capacity at 20 h. p. to each drill. There was actually installed one 80-h. p. and three 150-h. p. boilers, all being return-tubular with brick arch, cast-iron fronts and iron stacks, making a total boiler capacity of 530 h. p.

The selection of the compressors was governed by the plant on hand, and comprised one Rand straight-line, 16 by 24 in., of about 600 ft. capacity, two Rand straight-line, 20 by 30-in., each of about 1 000 ft. capacity. At times all these compressors were run at about 20% more than their normal speed of 110 rev. per min., and, roughly, their combined capacity was increased to 3 000 ft. of air per minute when working at their maximum. The three 150-h. p. boilers provided an ample supply of steam, without the assistance of the 80-h. p. boiler, and the results indicate that the preliminary allowance was high, and that about 15-h. p. boiler capacity in this instance was sufficient to compress 100 ft. of air per minute to the gauge pressure of 100 lb.

Contributing to this economical boiler capacity was the use of anthracite coal under forced draft from a steam jet, making practically perfect combustion, and a more than usually tight distributing pipe line.

Whenever a pipe line is to be determined, there is always a balance to be drawn between small size, large friction, and small first cost, and the alternate. Without pretending to any accurate determination of these features, a practical balance for this particular work was to run a main 6-in., sleeve-connected, wrought-iron pipe from the compressor, past the first shaft, and up to the second. This pipe was reduced to 4 in. between the latter and a receiver at the north portal. A 3-in. pipe carried the line to the bottom of each shaft, and the further extension toward the several faces of attack was by 2-in. pipes resting on the bottom. Temporary connection between the end of each pipe and the drills was made by 50 ft. of 2-in. rubber hose, distributed to the several drills by 1-in. rubber hose. The main 6-in. pipe line was laid uncovered in the streets, over and parallel to the tunnel, and was laid during hot weather. On account of its position in the street, the pipe, while slightly sinuous in detail, was very nearly straight in its

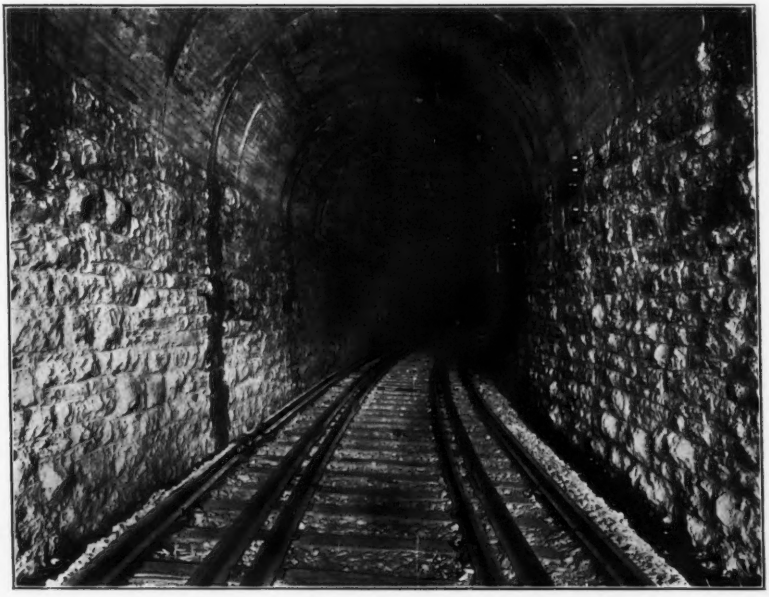


FIG. 1.—SCRANTON TUNNEL; MASONRY-LINED SECTION, WITH RUBBLE SIDE WALLS AND CONCRETE ARCH.



FIG. 2.—SCRANTON TUNNEL; MASONRY-LINED SECTION, CONCRETE THROUGHOUT.

general direction. Expansion bends in the pipe were impracticable on account of its location, and as expansion joints are costly and unreliable, the pipe was laid without any appliance to take up the change of length caused by variation in temperature. The line thus laid gave no trouble in passing through the changes of temperature from summer to winter, and from winter to summer.

The general method of tunneling was to carry the bench and top heading together, with the heading from 50 to 75 ft. ahead. A traveling framework, of half the tunnel width, and with the top at a lower elevation than the top of the bench, was mounted on wheels, which ran on temporary rails. The frame admitted the passage of two cars—one to be run up to the bench at its side, and the other underneath. Either car could be loaded by chutes from the platform, and, at the same time, by shoveling the bench excavation. The connection between the traveling platform and the unexcavated portion of the bench was formed with 4-in. lagging built into a plank 24 in. wide, thus making a wheel-barrow run-way between the face of the bench and the movable platform. The heading spoil was loaded into wheel-barrows, wheeled over the plank and dumped through the chute on the traveling frame, the whole operation being performed without interfering with the loading of the bench spoil.

When it became necessary to blast, the planks were simply loaded on the frame and the latter moved back on its wheels to a safe distance.

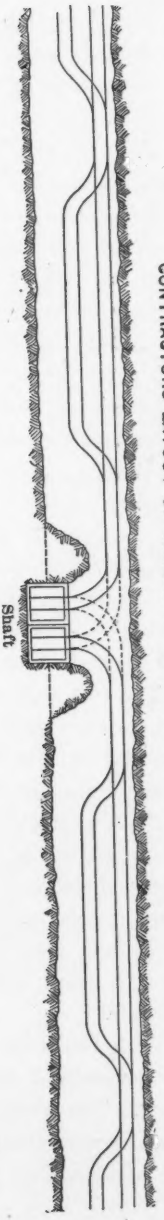



FIG. 3.—CONTRACTORS LAYOUT OF TRACKS AT SHAFTS FOR HANDLING SPOIL.

The foregoing method seems to be so simple and effective as to be scarcely worth description. Other ways of handling bench and heading material at the same time are advocated; nevertheless, the method outlined seems to the writers to be the simplest and cheapest.

A peculiarity of the bench rock, in part of this tunnel, modified considerably, not only the foregoing procedure, but also affected the timbering. That peculiarity was a consequence of the combined hardness and tenacity of the bench material. To break it out required so much explosive that the rock was blown lengthwise of the tunnel with such force as to wreck any permanent timbering erected within 200 ft. In addition, block-holing the spoil was always necessary after the first blasting. The interruption to the work of loading the heading spoil, caused by moving the traveling frame out of danger, was so serious as to render it impracticable to continue the simultaneous excavation of the heading and bench. The heading material, while requiring timber for permanent support, could be left temporarily unsupported; the support being required, not to hold up an overhead mass, but to prevent and support exfoliation, slabbing and weathering of the material. On account of these features, the heading was worked for a reasonable distance ahead, and the force then dropped back and split the bench in two lifts.

The full section of the tunnel was carried without timber support, to the extent of as much as 300 ft. The timbering was then erected from the bottom, and its full section was completed and packed from the floor of the tunnel.

*Drilling and Shooting.*—The typical plan of drilling the heading was, as shown in Fig. 4, with the eighteen holes fired in the order thereon indicated. From two to six additional holes were often found necessary. The longest holes were the cut holes fired first, which were from 8 to 9 ft. long. The widening holes were from 6 to 8 ft. long. The round was counted to make an advance of from 4 to 6 ft.

With two 3¼-in. machines, the time required to drill the holes was generally 7 hr. The total round drilled averaged about 140 lin. ft. The completion of the loading, wiring, firing by battery in series, reconnecting for the successive blasts, and the delay necessary between them for the explosive fumes to be blown out by com-

FIG. 4.

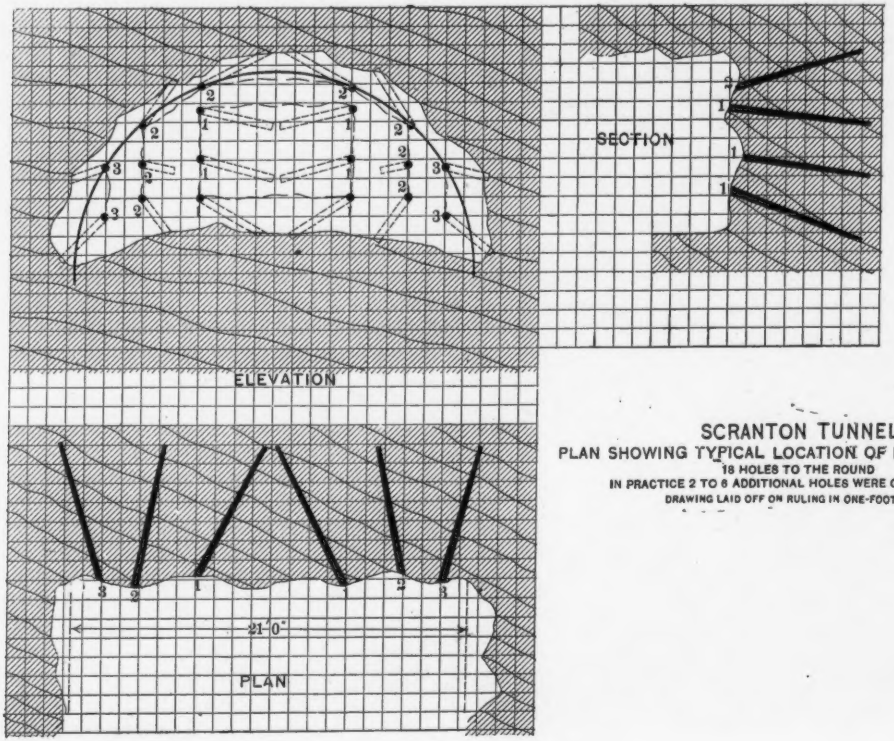

SECTION
ELEVATION
21'0"
PLAN
SCRANTON TUNNEL
PLAN SHOWING TYPICAL LOCATION OF BLASTING HOLES
18 HOLES TO THE ROUND
IN PRACTICE 2 TO 6 ADDITIONAL HOLES WERE OFTEN NECESSARY
DRAWING LAID OFF ON RULING IN ONE-FOOT SQUARES

FIG. 4.

pressed air allowed to escape for this purpose, consumed varying times, from 30 min. to 2 hr., or an average of, say, 50 or 60 min.

The delay from shooting was greatest in the portion of the tunnel excavated from the shafts. In this portion the fumes seemed to hang and accumulate, not only on the firing side, but also on the other side of the shaft, producing delays in both places.

The explosive was 40 to 50% dynamite, mainly the latter, and the cost per cubic yard, for explosives, caps, wires, etc., for all the excavation, was equivalent to the cost of 3½ lb. of 40% dynamite.

*Cars and Rail.*—The type and capacity of the dump cars used in tunnel excavation is a practical question of considerable importance. General conditions require a 3-ft. gauge. The cars have to be handled as single units up to the portals or shafts, and beyond. No method seems to be economical, except by hauling single cars by mules. The car, therefore, should be nearly equivalent to the hauling capacity of a mule, and must be open at the end so that in loading the least lift is required to reach its floor—the dumping will require change or reversal of position. The car, therefore, must be rotary. A car of the following description answers well in practice:

A rigid frame, with four 15-in. wheels, 3½-in. tread, 2½-in. axles; inside bearings, iron rotating spider; bed about 5 ft. 6 in. at back, 5 ft. 8 in. at front, 6 ft. long, with 18-in. sides, all inside measurements. Such a car transports about 1 cu. yd., solid, and weighs, empty, about 2 000 lb. The car is fitted with a removable tail board, like a cart.

A 20-lb. rail, with abundant cross-ties, can be used; but a 30-lb. rail is the more economical, in the end. Rails, in order to be handled down the shaft, should be in lengths of not more than 20 ft. The detail of moving ahead, in order to get the car up to the bench face, is arranged by placing, inside of the fixed rail, loose rails laid on their sides, with their heads against the web of the fixed rail. The car wheel flanges roll on the web of the loose rails, and the latter are slipped ahead at intervals until the excavation permits another length of fixed rail to be laid.

*Timbering.*—It will be noticed, Plate XX, that there were plans for two methods of timbering. One, the contract plan, was for solid timbering, with provision for concrete arching against its inside perimeter; the other was for voussoir blocks erected inside of

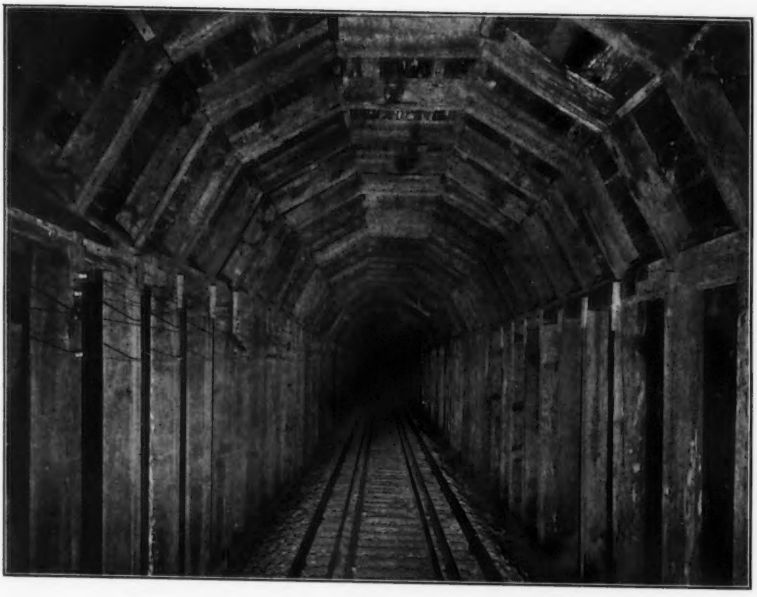


FIG. 1.—SCRANTON TUNNEL; PERMANENT TIMBER-LINED SECTION.



FIG. 2.—SCRANTON TUNNEL; SOUTH PORTAL.

Mrau

the masonry section and intended to be removed at some future time and replaced by concrete. Timber arching of 10 or 12-in. square arch blocks, with 3 or 4-in. lagging spanning the space between each pair of rims, is the standard of long experience. For economy and ease of erection and packing, and subsequent stability it cannot be improved.

The contract form of timbering, here designated as "segment lagging," for want of a better name, in which the lagging and arch blocks are, so to speak, the same, is ideal in some respects. It uses more timber per foot of tunnel, but gives stronger support per foot, saves in single-track tunnel, roughly, 1 cu. yd. of excavation per foot, and, where the tunnel is to be lined with concrete, furnishes a back form for the concrete, closely concentric to the soffit, thereby saving either an excessive use of concrete to fill the space between the masonry arch and the timber, or avoiding the formation of an extrados for the concrete where the arch is held to a regular thickness. It also avoids the subsequent expense, uncertainty and delay of packing about 1 cu. yd. per lin. ft. between the concrete and the timber.

Pre-supposing a short length of tunnel provided with this timber in place, it would seem to be an easy matter to add to it, with the result of fitting the successive segments to perfect line and stable position. Trouble comes from the variation in the thickness and squareness of commercial timber and from the difficulty of getting a true radial joint. The effect of any inexactness of framing is to carry the bearing on part of the timber and leave other pieces loose. In all timbering the integrity of its form and stability in position when it is packed depends upon the perfect wedging between the voussoir blocks and the perimeter of the excavation, assuming that the wall-plate is immovable in its position. When the arch block and lagged timber are used, the blocks require to be wedged, or propped, to the roof only for every 4 or 5 ft. of the length of the tunnel, then the lagging simply has to be laid on, and the packing space is free to be filled behind and around the props. The operations are few enough to permit the propping to be done thoroughly, without expense and delay.

With the "segment lagging," a very much greater number of pieces require to be wedged up. In the case of the 8 by 8-in. seg-

ment lagging of the plan, as against rims at 5-ft. centers, they are seven and one-half times as numerous per foot of tunnel. This wastes timber in props and wedging. The supports form an almost continuous line, converting the packing space into a number of separate pockets, lengthwise of the tunnel, in which thorough packing is difficult. On the other hand, in any form of timbering, the packing will settle away from the excavation, due to shrinkage of the timber, or shrinkage and readjustment of the packing material from the jar and concussion of blasting, or frequently from the settlement of the wall-plate itself. With the arch-block timbering, there being a free space above the timbering, the tendency of the packing is to settle and slide toward the haunches and open the inside joints of the haunch-blocks. With the segmental lagging, the settlement is confined to the separate longitudinal spaces between the lines of props, and does not become cumulative; therefore, there is less tendency toward deformation.

The experience of the writers has been that the "segment lagging" timbering costs very much more per thousand than the arch-block form. It should also be noted that the yard of excavation saved is not saved at the full price for tunnel excavation. All that is saved is the cost of loading and disposing of the spoil, and of a very small portion of explosive. The cost of all drilling, power and plant, and the general expense and profit, would remain the same per foot of tunnel.

If the company had desired to put in construction or permanent timbering, and to leave sufficient space to put in, at some future time, a masonry lining, without removing the original timber; and if it had had the option of putting in either the "segment lagging" form or the arch-block form of timbering, and could have paid the same unit prices for excavation, timber and packing in either case; there would have resulted a very material saving in cost per foot of tunnel by the use of "segment lagging," and, in the writers' opinion, a very much stronger timber arch would have been obtained during such time as reliance was placed upon it. With the Scranton prices and dimensions, the writers would estimate this saving, for equal masonry clearance, at about $2 per ft., if the same unit prices held.

For the reasons before stated, the contractor's unit prices, if he

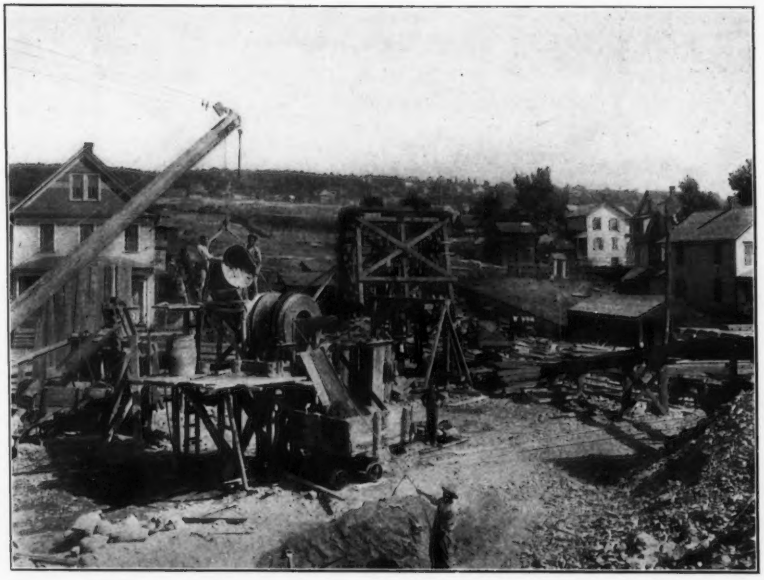


FIG. 1.—SCRANTON TUNNEL; HOISTING RIG, SHAFT NO. 1.



FIG. 2.—SCRANTON TUNNEL; SHAFT-HOUSING.

had the chance to consider the two forms in making proposals, would have to be higher for excavation, timber and packing in the case of "segment lagging." The experience of the writers is that these higher unit prices would more than overcome the apparent saving. In other words, if offered the construction of a single-track tunnel at a given price per linear foot of tunnel, with either form of timbering at the contractor's option, the writers would prefer to use the arch-block form, although it is believed that the cost of the two forms would be nearly equal.

Practical erection difficulties in "segment lagging," in its requirements for exact radial joints and in its multiplication of wedging, would lead to preference for the arch-block form as being more rapid and safe with rougher workmanship.

The foregoing comparison applies only to the method of timbering for average shale or rock tunnel, without consideration of its adaptability to masonry lining to be built afterward.

If the "segment lagging" timber is to be lined afterward with a concrete arch, the practical advantages of this form of timbering, in reference to future concrete, are very great. The advantages are mainly in reference to packing with solid concrete the whole space between the soffit of the concrete arch and the perimeter of the timbering with the minimum quantity of material, and, at the same time, holding very closely to some pre-determined thickness of arch. If the arch-block timber be in place, and the same thickness of arch concrete is required, there is the 12-in. space between the lagging and the extrados of the concrete to be filled in addition. If filled with concrete, there is required an extra quantity of from ¾ to 1 cu. yd. per ft.; if with dry packing, the same quantity, and with a support built up of concrete, packing, timber and again packing. By the "segment-lagging" method, there is the original dry packing above the timber, and everything below the timber is solid, making a better job with a saving of the intermediate packing.

*Lighting during the Tunnel Excavation.*—The writers have generally used gasoline (1-gal. tanks with open burners) for lighting tunnel work on the ground. Its portability, the opportunity of obtaining illumination at the right place, and its general flexibility overcome its high cost.

Gasoline, of course, is dangerous; the renewal of the lamp is a considerable expense, and occasional accidents are bound to occur. The heat, also, is very objectionable.

The accounts show that the cost of lighting, night and day, inside and outside of the tunnel, was more than $6 000, or, roughly, say, 6 cents per cu. yd. By months, it represents $500 per month for double-shift work, or, in another form, about $1.25 per ft. of tunnel.

The contractors returned to the use of gasoline after a previous experience with a tunnel of similar length but smaller section, driven with the use of the electric light. As the tunnels were of greatly different sections, and varied almost totally in material and method, the comparison is not at all fair, but electric light on that work cost about 11 cents per cu. yd. With the electric light there is a perpetual nuisance in replacing wires and broken globes, and it is troublesome to concentrate the lighting where it is needed most—right up in the heading at the front.

It is believed that, on an average, there will be found no material cost advantage in one method over the other, and the advisability of the method to be adopted will have to be settled by its facility in use. The writers have thought, heretofore, that the verdict was in favor of gasoline, but now believe that the electric difficulties can be overcome in part, so that, at least for long tunnels, it will be the better method.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## THE CHANGES AT THE NEW CROTON DAM.

### Discussion.*

By Messrs. Alfred Craven, George S. Rice and Charles S. Gowen.

Mr. Craven.

Alfred Craven, M. Am. Soc. C. E. (by letter).—One should not be permitted to infer, by a perusal of the *Transactions* of this Society, that one of the greatest structures of its kind, designed and partially carried to completion by one of its most distinguished members, had been a failure to such an extent as to necessitate its partial demolition and subsequent reconstruction on different lines, without a full discussion of all the reasons that really brought about the change. Such a conclusion as to failure would undoubtedly be arrived at by one familiar only with Mr. Gowen's paper, "The Foundations of the New Croton Dam," presented on February 21st, 1900, on learning subsequently of the radical changes which have since been made.

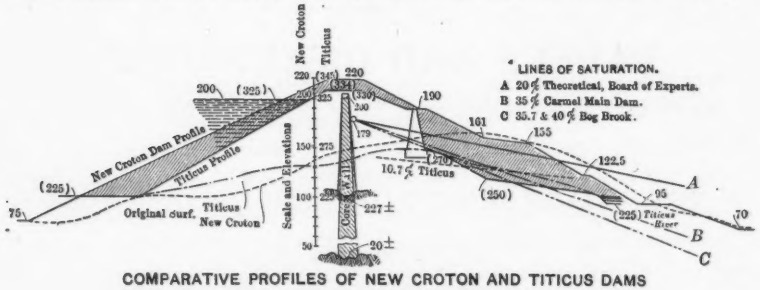
Fortunately, Mr. Gowen has now supplemented his original paper by the discussion of the changes made, giving substantial reason why, in his opinion, they were unnecessary.

William R. Hill, M. Am. Soc. C. E., who was primarily responsible for the radical changes made, has replied to Mr. Gowen's later paper, giving reasons why, from his point of view, the changes were advisable; he has given his views, as heretofore frequently repeated in the technical journals as well as in the daily papers, and supports these reasons by noting their endorsement by a Board of Expert Engineers, and others.

* Continued from February, 1906, *Proceedings*. See December, 1905, *Proceedings* for paper on this subject by Charles S. Gowen, M. Am. Soc. C. E.

Mr. Craven. It appears to be only proper, therefore, that the views, as to the changes in construction, of the engineer who designed this great work, the late Alphonse Fteley, Past-President, Am. Soc. C. E., should also have their place in this discussion.

Fortunately, Mr. Fteley's views are on record elsewhere. In *Engineering News* of December 12th, 1901, they may be found in full; herein will be noted such quotations, only, as bear particularly




COMPARATIVE PROFILES OF NEW CROTON AND TITICUS DAMS
(These are developed profiles on "lines of least resistance to passage of water." Elevations in parenthe es relate to the Titicus Dam.)

FIG. 4.

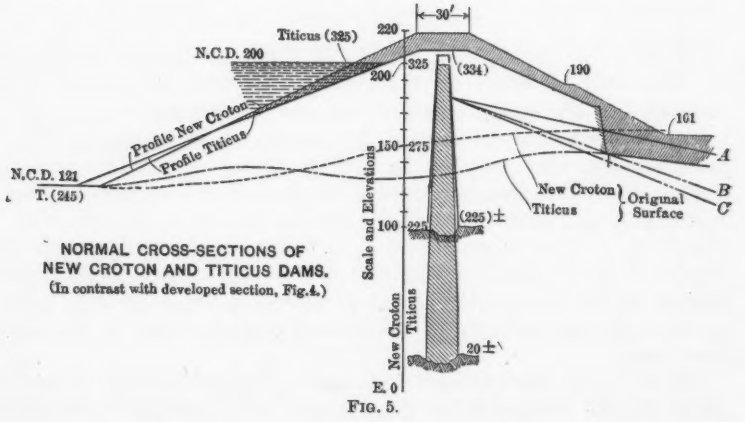



FIG. 5.

on the main questions involved. The writer also reviewed the subject at some length in *Engineering News* of January 12th, 1902.

Mr. Hill, in his argument on Mr. Gowen's recent paper, notes that Mr. Gowen has referred to the above-mentioned "rejoinders to the Committee of Experts without giving any information as to the contents of these rejoinders."

To avoid long technical descriptions and repetitions of arguments, and trusting somewhat to the reader's careful perusal of the

papers mentioned, the writer has reproduced here, in Figs. 4 and 5, his own drawings from *Engineering News* of January 12th, 1902. Mr. Craven.

Mr. Fteley, after calling attention to the hardpan formation in which the core-wall was to have been built, says:

"In instances of this kind, when a rock foundation is found within accessible distance under the central part of a dam, it is very usual to abandon the rock foundation and to let the foot of the core-wall step up into the earthy materials of the side hill."

He then cites the embankments of Bog Brook, Carmel Main Dam, Titicus "and many others" (see Fig. 3, page 609, of December *Proceedings*), and states:

"In the present case, however, the core-wall was extended down to the underlying rock into which a trench was excavated to receive the foot of the wall; this arrangement presents the additional advantage of establishing the high wall on an unyielding foundation.

"At the southern end of the central body of masonry where the embankment begins, the height of the surface of the side hill originally stood at an elevation of less than 60 ft. below the higher water mark of the reservoir; from that point south this depth gradually diminishes down to nothing. A large excavation has been made in the side hill to accommodate the earth slopes of the pits necessary for the construction of the masonry dam and of the wing-wall; these pits are obviously to be refilled, and it is through them that the large section, Fig. 2,* of the report is made."

Mr. Fteley, after taking exception to Fig. 2* of the Experts' report, which he very properly says "will convey an idea very different from what the facts will warrant," which indicates the refill of this pit as being a part of the earth dam, and which is furthermore taken so seriously by Mr. Hill, says:

"I may here point to the fact that, when building Titicus Dam, an extensive earth excavation was also made into the side hill on the north side of the masonry section in order to establish its footing and that of the adjacent core-wall on the rock foundation and, if a section of the structure were made on a similar 'line of least resistance' it would show the core-wall with earth embankments on each side, on a minimum slope of $1\frac{3}{4}$ to 1 with a height of 100 ft. A profile made on this 'line of least resistance' at Titicus Dam, in juxtaposition to profile No. 2,* would show a result in favor of the New Croton Dam."

The writer will here call attention to the fact that the Titicus Dam, which will be frequently referred to, has been taken generally as a matter of comparison, as it approaches more nearly to the New Croton Dam in its general features than any other dam of composite type.

* Fig. 2 of the Experts' Report is referred to here.

Mr. Craven. Mr. Fteley then considers the functions of an earth dam with core-wall, referring particularly to the case in point:

"Let us consider the two embankments of the dam separately, as they are called upon to act in a very different manner.

"The up-stream embankment will be in the water, and the (lower and larger part of it will repose, not against the core-wall, but against the main dam) from *A* to *B* (see plan herewith). When fluctuations occur in the reservoir, they will be so slow, on account of its vast area, that it may be said that no water will flow through the bank with sufficient velocity to displace any particles of earth; the only conditions left to be fulfilled are, consequently, that the embankment will be sufficiently water tight, and that it will not slough off or be washed off on the surface; the last condition will be met by covering the slopes as shown in the plans and specifications, with a layer of broken stone with heavy paving upon it.

"As to the condition of water tightness, it is sufficiently met, in my opinion, by the character of the materials to be used, which I have observed continuously for several years while refilling the excavation for the main dam.

"The up-stream bank of Titicus Dam, which is nearly 100 ft. high, with a similar slope, was built with materials finer than those used at Croton Dam, and, barring a slow and perfectly regular vertical settlement, which was expected, has acted in a very successful manner. For several years, whenever the height of the reservoir permitted, exact measurements were taken and the slope has never shown any mark of disturbance."

He then reviews the question of the materials used in the refill and embankment, as follows:

"Before construction, both at Titicus and at Croton Dam, earth excavated from the places where it was expected to take it for refilling, was dumped in the stream, care being taken to form the dumps of the finest materials. In no case did those dumps, left unprotected, show a slope steeper than 1½ to 1. A bank, standing at repose in water, cannot be compared to such hill sides as the experts have observed in the valley where they were acted upon by ground water; if their comparison in that respect were correct, no slope of any kind would be practicable, and not an embankment of the dams built in the Croton Valley and elsewhere, under similar circumstances, would remain standing.

"As to the resistance of such an embankment to the percolation of water, it is obvious that absolute water tightness cannot be expected; and the experiments made at the Cornell Hydraulic Laboratory only illustrate that point; at any rate, it cannot be expected that the results of laboratory tests, on very small volumes of materials collected on the ground, can throw any valuable light on the ultimate behavior of an extensive bank through which the water would have to percolate for a considerable distance before reaching the masonry parts of the structure. Adequate knowledge of the materials used or to be used, and experience, must be depended upon to pass judgment on those matters; moreover, a comparison with

the results obtained in the case of the dams built in other parts of the valley show that sufficient water tightness can be confidently expected from the proposed embankment." Mr. Craven.

The writer will remark here that the Board of Experts, while objecting to the quality of the materials used in this embankment and fill, remark:

"All the tests indicated that this material, which we found to be almost identical in character with that which has been used in the construction of all the earthen dams in the Croton Valley, is permeable to water under any head from 3 to 150 ft., and that when exposed to the direct action of water it disintegrates and assumes a flat slope, the surface of which may be said to be slimy."

This statement (a portion of which is quoted by Mr. Hill), while evidently intended to be condemnatory of the material used, might well be considered, in view of the fact that of the ten earth embankments of the dams in the Croton Valley, all have successfully stood the tests from 10 to 25 years, as fully proving its unquestionable value in an embankment.

Mr. Fteley then reviews the functions and conditions for the down-stream embankment:

"The conditions under which the down-stream embankment would have to perform its functions would be entirely different. Nothing need be said of the water that may enter the bank from springs in the side hill or from the rain; the conditions in that respect will be the same as have always existed, with the difference that the turf on the surface will shed the greater part of the rain. There remains the water which will find its way through the masonry or through supposed deep fissures in the rock formation. As no water is expected to pass through the central body of masonry, the surface to be considered is limited to that part of the core-wall adjacent to the refilling of the excavations or to the embankment. What amount of water can find its way through the wall at that point can be appreciated from a comparison with the other dams mentioned in the report and from the comparative thickness of the masonry. In the majority of the cases referred to, the walls are of less thickness, and although the lower embankment will contain, as must be expected, a certain amount of water, the tests made by the experts indicate that a very small volume of it will flow through the wall. At Titicus Dam, where the wall has more thickness, the indications are that very little, if any, water finds its way through it; in the present case the wall, for the greater part of its height, at the points where the pressure is highest, is 18 ft. in thickness and built of excellent masonry. From these considerations the conclusion is consistently reached that, in view of the character of the up-stream bank and of the core-wall, a very small amount of water will reach the down-stream bank from those sources."

He then takes up the question of danger from saturation of the down-stream embankment, and questions the propriety of the arbi-

Mr. Craven.

trary selection by the experts of the conditions in the outer bank of the Middle Branch Reservoir as a guide on which to base an arbitrary line of saturation—to govern in such cases, saying:

"The experts show a certain* 'line of bank saturation' as that likely to obtain in the present case. They base their statement on the observations taken by them at the various dams built in the Croton Valley; they find that the maximum safe height of an earth embankment with slopes of 2 to 1 would be 'on the bases of the loss of head and saturation at Middle Branch, 63 ft.; Bog Brook, 100.6 ft.; Titicus, 82.3 ft.; Amawalk, 72 ft.; Carmel Main Dam, 102.5 ft.' I fail to understand on what basis they state that from their observations the high embankment adjacent to the masonry dam would nearly approach the Middle Branch rate; such a conclusion would presuppose a complete knowledge of the comparative materials used, of the quality of workmanship, and of the various conditions existing during construction, which cannot now be obtained, as the Middle Branch Dam was built more than twenty years ago.

"Titicus Dam, with its high embankment and its heavy core-wall, is the structure to which can be best compared the New Croton Dam in several respects, and the experiments show that very little water, if any, finds its way through the core-wall, the water in the outer embankment standing 40 ft. below the reservoir level. A similar result is expected in the present case, and should a small amount of water find its way through the wall, the lower embankment, which is to be formed of comparatively porous materials, would allow of sufficient drainage, inasmuch as (to quote from the expert's report), 'the slope of the surface of the saturated earth in the bank is determined by the solidity of the embankment.'

"The Auxiliary Carmel and Titicus Dams show very favorable results, although the lower banks were formed of fine materials, none others being found within reach; with comparatively porous materials they would have shown steeper slopes of saturation. I cannot see the truth of the statement that 'the more compact the material of which the bank is built, the steeper will be the slope of saturation.' With compact material, the sectional area of flow is larger below a given level than with porous material, and as the bank slope is one determining factor of the line of saturation, this line tends to approach the slope line. With porous material in a down-stream bank the slope of saturation is steeper and the area of flow less. Unless the water finds its outlet on the face of the slope of the embankment, the slope of saturation will also be regulated by the fact that it will reach the ground-water level at a point near the toe of the slope.

"At the New Croton Dam, the down-stream bank has a 2 to 1 slope for a depth of about 60 ft. below high-water mark, and the unusual width of the top of the embankment is equivalent to a flattening of the slope. Below this, the retaining slope along the down-stream face of the main dam (on the 'line of least resistance') has a general inclination of nearly 3 to 1.

"The experts suggest that the alleged lack of stability would be,

* These lines of bank saturation are shown on Figs. 4 and 5.

to a large extent, overcome by flattening the embankment or by facing the lower slope with a revetment of heavy stone paving; these two suggested additions are, in my opinion, unnecessary; if I were to suggest an improvement to the present plan, I would recommend the drainage of the lower parts of the embankment; this work could be done on an extensive scale, at a comparatively trifling cost, with excellent results." Mr. Craven.

After discussing other features of the masonry dam, Mr. Fteley concludes as follows:

"Economy of design, when properly applied, is one of the main principles of engineering; it was undoubtedly given due weight in this instance, and it should not be departed from without the clearest demonstration that the proposed change is a necessity. It is not thought that the experts' arguments would produce that conviction on those experienced in the construction and maintenance of earth dams, and their determination of a probable line of saturation does not appear to be logically deduced from their observations of existing dams, or to be based on a sufficient study of the mode of percolation of water through fine materials."

Mr. Hill remarks:

"Although this paper is entitled 'Changes at the New Croton Dam,' it treats of only one of the several changes that were made in the plan."

In reference to other changes, Mr. Fteley remarks:

"The experts object to the original plan of the dam, which they call unjudiciously designed, on the grounds that no provision had been made to meet the contingency of a sudden and exceptional flow of water due to a cloud-burst or to other causes. The fact is that the original design was especially devised to meet that condition. Although the surface of the reservoir, covering thousands of acres, is so large that it would have a great equalizing power, the contingency of a sudden flood causing the overtopping of the masonry dam was carefully considered. To that effect, the top of the embankment was kept much above the crest of the masonry and a large amount of rock from the excavations was ordered to be placed on the top of the filling, below the dam, to prevent a harmful disturbance of the surface. The contract drawings are not at hand, but it is well understood that they are of a general character and cannot be expected to show all the details of the work, but the connection of the top of the embankment with the crest of the dam is shown on Sheet 22 of the Report of the Aqueduct Commissioners of Jan. 1, 1897, and the necessary orders for the performance of the work were given.

"I learn by the report of the experts that changes have recently been made, one being the raising of the crest of the masonry dam. The reasons for that change in the plan are unknown to me. I agree that it is injudicious, as it destroys a feature which was considered very important. The calculations for the stability of the dam were made in view of the original elevation of the crest."

Mr. Craven.

The experts themselves say:

"The masonry dam should not in any case be built higher than was originally designed. Such a change destroys the harmony and efficiency of the design which, having been scientifically determined, should be rigidly adhered to."

Still, Mr. Hill persisted in raising the masonry dam in spite of this admonition; in other words, the views of the Board were to be given weight only in so far as they agreed with his own.

The writer will now comment on the subject from his own point of view.

Unquestionably, the vital point to consider, and the one which should receive most serious thought, is the integrity of the down-stream bank of an earth dam.

If formed of too fine material, the flow of water through the bank, assuming that some will pass the core-wall, will be retarded, and the upper plane of saturation will take a flatter slope than through more porous material, giving a greater area of saturation, and may eventually reach the outer slope of the embankment, causing a sloughing off of the material and thus endangering the structure. If this is guarded against, the bank is in no danger; hence, while the outer bank is secure, the dam is safe, even though there may be considerable settlement.

The experts, discussing the question of saturation, to which they properly gave paramount consideration, established an arbitrary and extreme line of saturation, which indicated that the foregoing condition of liability to sloughing of the bank might result.

They concluded, however, that this assumed condition for the New Croton Dam "might be overcome to some extent by flattening the slope of the bank * * * so as to bring the probable slope of saturation not less than 10 ft. below the surface of the bank."

Mr. Fteley suggested, but did not consider it essential, that the same results could be attained by draining the outer bank. It seems clear, therefore, that either of these simple methods might have been followed, thus removing the slightest cause or necessity for the great expenditure of money and time which have resulted in the methods followed—the cost would probably have been less than $50 000, as against $1 000 000 actually expended—and the loss of time in completion, amounting to two years or more, would have been obviated. Why was this not done? The experts say "it would add largely to the cost and would disfigure the appearance of the dam."

In discussing the question of saturation, Mr. Fteley takes exception to the views of the experts wherein they contend that "the more compact the material of which the bank is made, the steeper will be the slope of the saturation."

The saturated portion of the dam is simply that portion below

the inclined plane of the surface of the water in the bank, whether the material be ever so coarse or ever so fine; porosity is merely a degree of compactness or *vice versa,* and all bank material will absorb water. Mr. Craven.

Slope implies motion in water, and there is no absolute retention of water in the outer bank of a dam having its base below the plane indicated by the loss of head in passing through the inner bank and then through a further obstruction of either masonry or puddle. It is simply a partial retention, with motion through the bank, governed entirely by the degree of porosity of the material, and, unquestionably, the more porous the material in the bank, the steeper will be the slope at which water will pass through it. Just the contrary is claimed by the Board of Experts in their report.

Comparing the earth portion of the New Croton Dam generally with that of the Titicus Dam, referring to Figs. 4 and 5, and accepting the definition of the effective height of a dam embankment as "the difference between the level of the water at high-water mark and the level of the point of intersection of the down-stream slope and the plane of the valley bottom," it is evident that the New Croton embankment is only about 30 ft. higher than that of Titicus Dam, instead of twice as high. It is true that the New Croton core-wall has nearly twice the height of that at Titicus, but in the very nature of this case, where both walls are carried to the underlying rock, this difference in height is more apparent than real; more properly speaking, the difference is in depth below the base of the dams.

It will be seen by Fig. 4 that there is only 30 ft. difference in the embankment height: The New Croton has an interior slope of 2 to 1, Titicus of 1¾ to 1; the New Croton, on its outer slope, has a variable profile much increased in value by wide bermes carrying it far beyond the profile of the Titicus, which also has a variable profile abruptly broken by a wing wall, which was not intended as, and is not, a barrier to filtration.

This wall has only a shallow foundation, and, as will be seen by reference to Fig. 4, the slope of saturation for the Titicus Dam, as established by the experts, will pass under this wall and out through the restored surface beyond, which, in accordance with their theory, renders the bank unsafe.

The excess of the New Croton profile over the Titicus, as may be plainly seen, is due to its greater width at the water line; the New Croton having a width of 115 ft., the Titicus of only 72 ft. These measurements are on the delevoped "lines of least resistance." (The actual widths on normal sections are 110 and 74 ft.; see Fig. 5.)

This excess in the New Croton is divided between the outer and inner banks, and it shows largely in favor of the New Croton Dam, as was stated by Mr. Fteley.

Mr. Craven.

Fig. 5 shows comparative sections of the two dams at right angles, or normal, to the slopes, taken, in each case, near the dividing lines between the earth and masonry dams. It represents truly the actual differences in sections, which differences, as in the case of the developed section, are unquestionably in favor of the New Croton embankment. It shows a dam which, by the definition of effective height, is only about 40 ft. high. This is just south of the heavy wing wall.

The developed profiles on "lines of least resistance" (Fig. 4) have been used in making comparisons only for the reason that they are a creation of the experts, and it is the only method by which the New Croton embankment could be made to appear higher than any of the dams now in successful service in the Croton Valley.

Assuming, however, that the outer refill is to be treated as a part of the bank proper, then, on Fig. 4, are produced the several slope lines of saturation as determined by the experts for the other dams.

The theoretical 20% line of the experts would indicate a danger point on the developed profiles, while the lines of Bog Brook and Carmel Dams indicate absolute safety, passing far below the 10-ft. limit of the slope of the bank, a limit of safety fixed by the experts, which in itself is rather an excessive requirement.

On the other hand, all the lines indicate unsafety in the Titicus profile. These lines are plotted with the experts' assumption of a loss of head of 17% of the depth of water in the reservoirs.

The writer agrees fully with Mr. Fteley that there is nothing whatever to justify the adoption, by the experts for New Croton Dam, of the Middle Branch line of saturation as against the lines of Bog Brook and Carmel.

The experts admit that the core-walls and embankments of Amawalk and Middle Branch were not as carefully constructed as those of the other dams, yet they arbitrarily select the Middle Branch line of saturation to apply to the New Croton Dam.

For the purpose of showing his alleged "inadequacy of embankment" of the New Croton Dam, Mr. Hill compares the width of base and slopes with the broad base and flat slopes of the Amawalk Dam. It must be borne in mind that the Amawalk Dam embankment was made in the form of a great earth fill, no attempt being made to compact the material by rolling or ramming, but trusting to the great mass of material to supply the equivalent of more careful methods of construction. During the long period of construction the material was allowed to settle as best it would; therefore, it is not to be taken properly as a comparative construction with the dams built by the Aqueduct Commission where every precaution was taken that is essential in the construction of embankments,

fully justifying the comparatively steeper slopes and more contracted bottom widths. Mr. Craven.

There is one point in Mr. Hill's argument to which he apparently attaches great weight; it is the alleged "unstable foundation of the embankment."

In articles which he has caused to be published elsewhere, he dwells as follows on this feature of the work:

"This embankment was hazardous because of the unstable nature of its foundation. It was founded over a great refilled pit (giving dimensions of pit). It would be impossible," he says, "to refill this pit as compactly as the original ground, hence the safety of the reservoir was dependent, not only on an embankment of a problematic section, but this problematic section rested upon an unstable foundation."

* * * * * * * *

"The water would be afforded freer access through the refilled material of the great pit than it would have in ordinary cases where the wall below the original surface of the ground is in a narrow trench and protected by the original soil."

* * * * * * * *

Also, "a fourth objection, * * * the permeable and light character of the earth of which the embankment was made, but even with the best material, an embankment so constructed would be insecure."

In other words, his contention is that a made embankment cannot be as solid as, and will permit the passage of water more readily than, earth in a natural state.

In his argument on Mr. Gowen's paper, he has repeated these statements in a somewhat modified form.

The well-known facts are, unquestionably, just the reverse of the above. A properly made artificial embankment, either puddled or rolled in layers, undoubtedly contains a greater quantity of material per unit of volume than an equivalent volume of the same earth in its original position, and is less pervious to water. This rule frequently leads to the removal of a considerable quantity of material, and to a refill, often with the same material, rather than build on the natural surface; and the writer, from his knowledge of the conditions at the New Croton Dam, cannot conceive why there should be in that case any exception to this generally accepted rule.

The fact must not be lost sight of that the material replaced below the lines of the natural surface of the ground is simply a refill confined in a great pit, and no amount of reasoning over this condition can make it an embankment.

This refill could be made, and in fact much of it had been made, to a height of about 100 ft. above the low point of the core-wall,

Mr. Craven. with such care as to preclude the possibility of bringing any undue stress on the core-wall that would tend to its rupture, and, furthermore, when it was again finally removed, the wall was found intact.

It is interesting, therefore, to know (see both Figs. 4 and 5), that above this line of refill, while the dam is no higher than that at Titicus, the embankment, as pointed out by Mr. Fteley, is far more in excess, in its factor of safety, than that of Titicus; and the writer does not believe any one will question the adequacy of the latter.

Properly made embankments will not settle materially; in fact, several cases of dams of considerable height can be cited where accurate levels have been taken on the tops of the dams when completed, and again, long after the reservoirs had been filled with water, additional observations have shown absolutely no settlement of the earth banks. In cases, however, where settlement does occur, if due to the action of water, it must mean the displacement of so much water and a consequently greater compacting of the bank material.

In regard to percolation and filtration through sands and soils, it might be well to study the paper on the Bohio Dam, Panama Canal, by the late George S. Morison, Past-President, Am. Soc. C. E., presented before the Society on March 5th, 1902, and the discussion thereon by Frederic P. Stearns, President, Am. Soc. C. E., on the North Dike of the Wachusett Reservoir; they are instructive and also may be considered as pertinent to the subject under consideration.

The late E. Sherman Gould, M. Am. Soc. C. E., an engineer of extended experience in the construction of dams and reservoirs, has written:

"An earth embankment provided with a heavy masonry center wall carried down to a firm substratum, or, failing in that possibility, to a considerable depth below the surface, the depth being in inverse ratio to the compactness of the material, and well bonded into the sides of the valley, forms one of the best and safest dams which can be built."

It has further been remarked that:

"Of the materials used in the construction of dams, earth is physically the least destructible of any. The other materials are all subject to more or less disintegration or changes in one form or another, and in earth they reach their ultimate and most lasting form."

One more reason has been given, by Mr. Hill and the Board of Experts, why an earth dam should not be built more than 100 ft. in height, and that is a lack of precedent. If engineers wait for precedent surely no advance will be made in any form of construction. There is absolutely no reason why they should stop at 70, 100

or 200 ft. in height for an earth dam; it is merely a question of necessity or expediency. The profession of engineering and architecture would long ago have been at a standstill if "precedent" had been waited on. In this case, however, there is no lack of precedent; Mr. Gowen has cited several cases of earth dams, 100 ft. or more in height, which in the opinion of the writer are, all things considered, much bolder in their conception than the New Croton Dam. Mr. Craven.

Again, if "precedent" is to be sought to solve the question, it should be used negatively; if dams of more than 100 ft. in height had been properly built and had failed, a precedent might then have been established as against further efforts.

Had the test wells been made in the Middle Branch embankment 15 years ago; had the same results been obtained as now, followed by the same conclusions; had these conclusions been accepted, then it is self-evident that the Carmel, Bog Brook and Titicus Dams would never have been built, at least on their present lines; still they stand to-day as masterful examples of good construction and contradictions to the theories and conclusions of the experts, and it is so with many other earth dams with no flatter slopes than are proposed for the New Croton Dam.

In conclusion, the writer desires to say that, in his opinion, there was absolutely nothing to fear from the completion of the New Croton Dam on the lines as laid down in the original plans, knowing full well the care with which these plans were developed and were being carried out.

GEORGE S. RICE, M. AM. SOC. C. E. (by letter).—The writer is pleased to note Mr. Gowen's careful consideration of the engineering questions involved in the changes lately made in the New Croton Dam. Mr. Rice.

The subject is one in which engineers, especially those employed by the Aqueduct Commissioners since the original investigations of the various sites, have been very much interested. Knowing the extreme care with which this and other sites were investigated, and having a knowledge of the conditions which existed there, as well as the immense amount of work done by Mr. Fteley in connection with the theory and design of high masonry dams, it is a source of regret to note the criticisms of, and the changes in, the plans originally contemplated for this great work. Mr. Fteley's experience in this class of work was probably greater than that of any engineer of the present time, he having been equipped, not only theoretically, but practically, with a knowledge of the subject.

The writer realizes that it is perfectly natural for the engineer, in considering the question of a dam of this nature, to assume instinctively that a masonry dam from one side of the valley to the other would be an ideal solution of the problem; but when one is

Mr. Rice. familiar with the results of the construction of dams in America, more particularly in connection with such large works as the dams for the additional water supply of the City of Boston, and also the extensions in recent years for the water supply in the Croton Valley, the consummate skill with which this work was originally designed is perfectly apparent. This plan contemplated a masonry dam where the foundations were adapted for it, and when peculiar conditions were found at the southerly end of the Cornell site the subject was treated purely with an idea of meeting the conditions thus found.

In the design of this dam, Mr. Fteley's whole idea was to erect a masonry structure, where it was found better in an engineering way, but when, in his judgment, the conditions warranted, he used a corewall with an earth dam, and showed in this the very best engineering, that is, good construction and economy. His judgment in this matter was based upon the nature of the material in the Croton Valley, with which he was fully acquainted, as he had designed and constructed several dams there. In the writer's association with Mr. Fteley, it was natural that he should have talked with him on this subject at various times, and consequently he was familiar with the reasons and purposes of his method in designing the dam.

In the last few years of Mr. Fteley's life it was a gratification to him to feel that the changes in the dam reflected in no way upon his judgment; he realized that these changes were made by those who did not have a full knowledge of the subject, and under the circumstances could not have had the experience, and that, therefore, the criticisms were illogical.

In the construction of this work Mr. Fteley had the advantage of having assistants who were experts in this particular line; and if Mr. Hill, as Chief Engineer of the Aqueduct Commission, had consulted members of his own staff and followed their advice, he would have had the command of exceptional talent in this class of work, would have profited by such experience, and, in order to carry out his plans, would not have been obliged to go outside for engineering advice. In reference to certain questions relating to the aqueduct work, it has been noticeable that Mr. Hill followed the advice of his consulting engineers only when it seemed to suit his own ideas.

Mr. Hill, in his report to the Aqueduct Commissioners, in speaking of the changes, said:

"I make this recommendation after carefully studying the situation and plan, and I know that I am absolutely right," etc. etc.

Such an assumption, on the part of an engineer occupying Mr. Hill's position, would seem to show that he lacked a full grasp of this subject.

Mr. Rice.

The writer agrees with Mr. Gowen that the changes which have been made in the completion of the dam were made at an extra cost to the city and a delay which would not have obtained if the original plan had been carried out, and, in his opinion, the dam as reconstructed is no better in carrying out its purpose than the earth section as planned in the original design.

Mr. Gowen.

CHARLES S. GOWEN, M. AM. SOC. C. E. (by letter).—In reviewing Mr. Hill's communication the writer finds it necessary to call attention to the fact that in the paper under discussion it is definitely stated that its particular purpose is to refute the statement made that the foundation of the core-wall was unsafe; accordingly, the special object of the various sections and views submitted, together with most of the text, is to illustrate this point. The general question of the changes advocated by Mr. Hill was assumed by the writer to have been so thoroughly discussed in the engineering press that the reports and articles published are merely alluded to as justifying him in his contention that the changes were unnecessary. The above explanation seems to be called for, as Mr. Hill states that the writer makes two general contentions, the first of which is that the former plan of the dam (that of September 16th, 1896) was adequate, and he then proceeds to discuss and criticise, in this connection, the plans, sections and statements offered in reference to the second and main contention as to the adequacy of the core-wall foundations.

Mr. Hill states that the only cross-section submitted is one of the embankment and core-wall at a point about 170 ft. from the end of the stone dam. Seemingly, he does not bear in mind that this section is to show the conditions at the most questionable point of the dike of granular limestone, concerning which the criticism of the safety of the core-wall foundation was made. He also forgets, apparently, in criticising the developed section, that this was made to illustrate conditions with reference to the same point in the limestone dike, and that it was made on the lines of least resistance (so-called) to percolation, in exact accordance with the plan pursued by the Board of Experts* in their report on the general question of the effective resistance of embankments and core-walls to percolation, and the resulting condemnation of the core-wall plan of the dam. He also says that it is a mistake to state that the up-stream slope of this embankment of the developed section is about 4 to 1. That there is no mistake about this, is apparent when it is noted that in this section the width of the embankment at the top is nearly 200 ft., most of it lying on the upper side of the core-wall line, which, with the slope below, as shown, is the equivalent of more than the slope claimed, particularly when the material lying above any ordinary slope line demanded at this point is taken into account.

*See Report of Board of Experts, *Engineering News*, November 25th, 1901.

Mr. Gowen. Mr. Hill's citation of the Mill River Dam failure, in order to controvert the writer's statement regarding the causes of failure of earthen dams, calls for comment, and in reply it may be said that the report of the Committee of the American Society of Civil Engineers which was appointed to investigate this matter (Messrs. Francis, Worthen and Ellis) states, in view of the crude methods used in the design and execution of this work "it is obvious that this cannot be called an engineering work;" and also, "no engineer, or person calling himself such, can be held responsible for either its design or execution."

In defining his position in the premises, regarding the general question of the changes made at the New Croton Dam, Mr. Hill states that it is not unreasonable to expect that conflicting opinions will arise as to the efficiency of a plan of a reservoir bank. Further on, he states that his recommendation to remove the core-wall was based on his opinion that the plan was inadequate, and he then, further, says in his report to the Aqueduct Commissioners recommending these changes, "I know I am absolutely right." Continuing, he instances the unanimous opinion of the Board of Experts supporting him, and the further concurrence of engineers in the employ of the city who were asked to give their opinions by the Mayor; and he accordingly concludes that, as far as the general public is concerned, great weight has been added to his conclusions.

In view of the foregoing, which, in the main, is a contention of absolute right by Mr. Hill, as to his position in the important matter of these changes, it is certainly proper to call his attention to the fact that this dam was originally designed after careful research and study, and its construction was supervised by an eminent engineer who had a long experience in the construction of high dams of various designs, and whose success in results has not been surpassed. A comparison of Mr. Fteley's professional record, in this respect, with that of any of the engineers whose dicta or opinions have been cited as bearing on these changes, would certainly warrant the claim that there is at least room for argument in this matter. A record of many years of notably successful professional work along certain special lines cannot be ignored, nor can there be assumption of absolute right in conclusions without at least prompting the query as to what qualification or authority there may be to warrant it.

As to Mr. Hill's contention that the first important change in the plan of the dam was made in September, 1896, before his accession to the position of Chief Engineer, and concerning his remarks in relation thereto, attention is called to this point, that this change was provided for in the specifications of the contract, and that the general plan defining the length of the main dam was tentative only. This change may be considered simply as a determination, of the

Chief Engineer who originally designed the dam, of the position of the end of the masonry structure. This determination was reached after the information regarding the foundation material which the excavation afforded had been considered, and the principal motive for making it was the reduction in the height of the embankment above the restored or refilled surface. This height, accordingly, was reduced to about 50 or 60 ft. The question of the depth of the core-wall below the refilled elevation did not enter into the settlement of this question, except as it was incidental to the reduction of the embankment height. It is perhaps well to say that this determination or change involved no question of taking down work already done, and consequent delay, and that all plans for the progress of the work on the dam from the beginning were made in view of the settlement of this question at the proper time. Mr. Gowen.

The extreme height of the core-wall at the point of junction with the main dam was 183 ft., including the depth excavated in the rock for its foundation, which was perhaps 15 ft. At a point 25 ft. south of its junction with the main dam the core-wall height was 166 ft. This is cited to illustrate the rate at which the extreme core-wall height decreased as the foundation rock slope rose to the south.

In considering the general arguments advanced by Mr. Hill in support of this change, it may be said that his description of the conditions planned at the junction of the main dam and the core-wall is practically correct. He neglects to state, however, that the embankment was to be carried to Elevation 220, thus giving it a thickness or width of more than 100 ft. at ordinary high-water mark, and, as above noted, his extreme height of core-wall is too great. The statement that, at the end of the stone dam, its width was 164 ft., is also excessive, 130 ft. being nearer the mark.

In his discussion of the embankment, he claims it to be 150 ft. high. Granting, for the sake of argument, that this refill should all be considered as embankment, if the Board of Experts' definition of its effective height be taken as being determined by the difference between high-water level on the up-stream side and the toe of the bank on the down-stream side, the height of bank due to ordinary high-water level would be 130 ft., and to extreme high-water level it would be 136 ft., this being on the line of the developed section. As to its thickness at the base, conceding, again, for the sake of argument, the refill to be bank, we must also follow the section of least resistance to percolation shown by the report of the Board of Experts, and we have for the embankment a thickness of at least 800 ft., in place of 650 ft., as claimed by Mr. Hill.*

A height of 136 ft. is not excessive, nor is 800 ft. an exceptionally narrow embankment base, even in comparison with existing struc-

**Engineering News*, December 12th, 1901. Plan in Mr. Fteley's report.

Mr. Gowen. tures. This is particularly evident when the comparison is noted of existing conditions between this proposed plan and the similar conditions at the Titicus Dam, shown in Mr. Craven's article in *Engineering News* of January 6th, 1902. Here it is shown that the effective height of the Titicus embankment is about 25 ft. less than that proposed for the New Croton Dam, and that the increased thickness and dimensions of the New Croton Dam bank more than compensate for its excess in height. This, therefore, in the light of experience, cannot be claimed to be a problematic section, nor does there seem to be any proper question as to the stability of the fill described by Mr. Hill for the pit beneath this bank. This pit is a hole in the ground, the walls of which would surely retain the refilling, which would have been compacted by the tremendous weight of the refill and bank above Elevation 70, and to a degree at least equal to its original density; this, especially when it is considered that the compact hardpan taken from this part of the excavation did not extend to the bottom of the pit, but was underlaid by a thick bed of sand and gravel.

Mr. Hill lays stress upon the experimental character of the core-wall of 200 ft. height, having "no lateral protection or support whatsoever from the original ground." It is assumed that he refers to such support as would be afforded by the sides of a vertical trench sunk in the ground; but it is difficult to see what advantages there could be in the lateral support afforded to a wall in a trench refilled to a depth of 3 ft. or more on either side of the wall, compared with that due to a heavy refill or massive made bank carried up at equal heights on either side and compacted at least in its lower stretches by the great weight of the bank above. A refill, under such conditions, would certainly afford as much lateral support to any wall, however deep or high, as could possibly be afforded by the refill placed by hand in a narrow space between the face of the wall and the side of the trench, however carefully it was done.

The writer, therefore, cannot see that the depth of a core-wall below the elevation which defines the lower limit of the effective height of an embankment has any bearing upon the essential questions involved in this case, if such wall has a proper base.

As to the actual height of the embankment involved in this discussion, the writer cannot concede that that portion of the refill placed on both sides of the masonry dam at the south end below the original surface line has to be considered. The actual height of the embankment to be considered, that portion above the original surface line, was not more than 60 ft., and the refill below, forming, according to the claims of the Board of Experts and Mr. Hill, the remaining 76 ft. of the bank, should be regarded simply as a restoration of the general surface or topography. Experience with com-

bination dams varying in effective height from 25 ft. to the height of the Titicus Dam, which so closely approximates at this point the New Croton Dam, justifies this conclusion. Mr. Gowen.

For the same reason, *viz.*, experience with varying heights of combination dams, the fear that flow may take place along the face of a dam wall beneath the embankment is not warranted.

Finally, Mr. Hill refers to the permeable and light character of the materials used for the embankment, as stated by the Board of Experts, who are quoted as stating that it was permeable under any head for 3 to 150 ft., etc. The writer feels free to say that he cannot understand the meaning of such a statement which might possibly be explained by the unquoted context. However, he has this to say of the embankment material; that it was composed of gravel, sand, sandy loam and clayey sand, properly mixed and compacted, and that it withstood such proper tests as the Board of Experts made, not excepting tests for permeability and slope action under water.

As to the assumption that Mr. Hill's course in changing the core-wall section of the dam was in keeping with the report of the Board of Engineers (Messrs. Shunk, Davis and Croes) who, in 1880, recommended an all-masonry structure for a dam at the Quaker Bridge site, it should be said that there is no proper parallelism to be cited, as the prevailing conditions at the sites of the two structures in question were different.

Mr. Stearns, in sustaining the writer in his contention as to the safety of the core-wall foundation, has referred to the investigations of the Board of Experts regarding the saturation of dam embankments, and to its conclusions that, in a majority of the cases investigated, the indications were that the core-wall offered no greater resistance to percolation than the embankment. If these conclusions are right, it would seem to be evident that the embankments approach the core-walls in density, and that, furthermore, there can be little or no pressure to act at the base of the wall and thus aid percolation under it. Such indications are certainly not prejudicial to the earthen dam as a safe structure.

Mr. Craven's discussion embodies the principal features of his own and Mr. Fteley's papers concerning the changes in the dams, which were published in the engineering press and referred to in the writer's paper. The writer fully concurs with Mr. Craven as to the desirability, under the circumstances, of bringing these matters into the discussion, so long as the general questions regarding the changes were renewed by Mr. Hill.

The comments of Mr. Rice, referring to his professional association with Mr. Fteley at the time the studies for the New Croton Dam were being made, and to his knowledge of the conditions under

Mr. Gowen. which the necessary investigations were carried out, are certainly of value, as they give additional weight to the general belief that Mr. Fteley's professional conclusions were based upon intimate and scientific knowledge of essential facts as well as upon broad views, and that they were accordingly reliable and abiding.

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# PAPERS AND DISCUSSIONS.

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## TEST OF A THREE-STAGE, DIRECT-CONNECTED CENTRIFUGAL PUMPING UNIT.

### Discussion.*

By Messrs. W. B. Gregory, H. F. Dunham and Philip E. Harroun.

Mr. Gregory.

W. B. Gregory, Esq.† (by letter).—The writer has not had any experience with three-stage pumps, but, during the summer of 1905, he tested a two-stage, direct-connected, centrifugal pumping unit. This pump had 6-in. suction and 4-in. discharge pipes, and was driven by a direct-current motor on the same bed-plate. The discharge head was measured with a pressure gauge on the discharge pipe near the pump. The suction was measured with a vacuum gauge on the suction pipe near the pump; both gauges being carefully calibrated.

The total head was ascertained by reducing these observations to feet of water, correcting for the difference of level, and adding to the difference between the velocity heads in the discharge and suction pipes. Thus the pump is given credit for the velocity head it produces, as well as for pumping the water against pressures equivalent to the given heads.

The water discharged from the pump was measured by an 18-in. Cippoletti weir, placed in a tank with baffle plates arranged so that the water flowed quietly to the weir. The depth of the water over the crest of the weir was measured by an accurate hook-gauge.

The electrical readings were obtained from carefully calibrated instruments. The electrical losses were measured and corrections made.

* Continued from February, 1906, *Proceedings*. See December, 1905, *Proceedings* for paper on this subject by Philip E. Harroun, M. Am. Soc. C. E.

† Irrigation Engineer, Office of Experiment Stations.

Mr. Gregory. The friction in the pump and motor was obtained when the pump was not primed, and in getting the efficiency of the pump one-half was charged to each, assuming the friction to be constant for all loads.

TABLE 3.—TWO-STAGE TURBINE PUMP.

| Time. | Revolutions per minute. | Volts. | Amperes. | Electrical horse-power. | Suction, in feet of water. | Discharge, in feet of water. | Total head, in feet of water. | Depth over weir, in feet. | Discharge, in cubic feet per second. | Water horse-power. | Efficiency of pump and motor; percentage. | Efficiency of pump; percentage. | Efficiency of motor; percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9:50... | 1 000 | 140 | 101 | 18.95 | 2.20 | 136.2 | 142.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9:55... | 978 | 138 | 126 | 23.33 | 3.06 | 140.0 | 147.6 | 0.241 | 0.597 | 9.98 | 42.8 | 50.2 | 85.3 |
| 10:00... | 967 | 136 | 176 | 32.11 | 6.46 | 127.3 | 139.1 | 0.322 | 0.923 | 14.52 | 45.2 | 51.9 | 87.1 |
| 10:03... | 955 | 134.3 | 194 | 34.95 | 8.72 | 115.7 | 130.3 | 0.362 | 1.101 | 16.25 | 46.5 | 53.1 | 87.6 |
| 10:06... | 960 | 134 | 208 | 37.38 | 10.20 | 104.2 | 120.7 | 0.378 | 1.216 | 16.62 | 44.4 | 50.6 | 87.7 |
| 10:09... | 960 | 134 | 217.3 | 39.05 | 12.23 | 92.5 | 111.5 | 0.408 | 1.316 | 16.60 | 42.5 | 48.3 | 88.0 |
| 10:12... | 956 | 133.5 | 225 | 40.26 | 13.48 | 81.0 | 101.6 | 0 427 | 1.409 | 16.20 | 40.2 | 45.7 | 88.1 |
| 10:15... | 956 | 133.5 | 236 | 42.25 | 14.95 | 69.4 | 92.0 | 0.446 | 1.507 | 15.67 | 37.1 | 42.0 | 88.3 |
| 10:18... | 956 | 133.5 | 242 | 43.32 | 16.20 | 57.8 | 82.0 | 0.459 | 1.571 | 14.56 | 33.6 | 38.1 | 88.3 |
| 10:21... | 949 | 132.5 | 247.5 | 43.97 | 18.01 | 46.3 | 72.7 | 0.476 | 1.657 | 13.62 | 31.0 | 35.1 | 88.3 |
| 10:24... | 949 | 132.5 | 254.2 | 45.17 | 19.37 | 34.7 | 62.9 | 0.489 | 1.727 | 12.30 | 27.2 | 30.8 | 88.4 |
| 10:27... | 949 | 132.5 | 260.5 | 46.31 | 21.01 | 23.1 | 53.1 | 0.495 | 1.759 | 10.57 | 22.8 | 25.8 | 88.4 |
| 10:30... | 949 | 132.3 | 264.0 | 46.88 | 21.53 | 16.2 | 46.7 | 0.495 | 1.759 | 9.30 | 19.8 | 22.4 | 88.4 |

Observations were taken, beginning with the discharge valve closed, then opening it slightly, and again taking observations as soon as all the conditions were constant. This process was continued until the discharge valve was wide open.

Some trouble was experienced with the thrust-bearing on account of heating, but the test was not interfered with seriously.

The discussion of the efficiencies of centrifugal pumps in general is of great interest. The writer has had considerable experience in testing a great many varieties of these pumps during the last ten years. Before entering into a discussion of results, it will be well to define exactly what is meant by the term efficiency, which, in general, is the ratio of the output of a pump to the energy furnished to the shaft. With pumps used for elevating water it seems to be fair to use, for the output of the pump, the useful work, or a certain number of pounds of water actually raised through a distance, measured in feet. If the first quantity is expressed in pounds per second, the product of pounds by feet of head, divided by 550 will give the horse-power corresponding to the useful work of the pumps. Usually, the water is discharged with appreciable velocity, and, if the total output of the pump, including the piping, is to be

credited to the pump, the head equivalent to the velocity of discharge must be added to the height through which the water is elevated to obtain the total head. By either of the foregoing methods, the loss at the entrance to the suction pipe, and the friction losses in the suction and discharge pipes are charged to the pump. Mr. Gregory.

In testing pumps in which the velocities are high, as in the case of hydraulic dredges, and in any case where the pump is to be eliminated from its special arrangement of piping, the total energy developed by the pump is desired, so that comparisons may be made of the pump performance only. In such cases the pressures are obtained near the pump on the suction and discharge pipes, and the

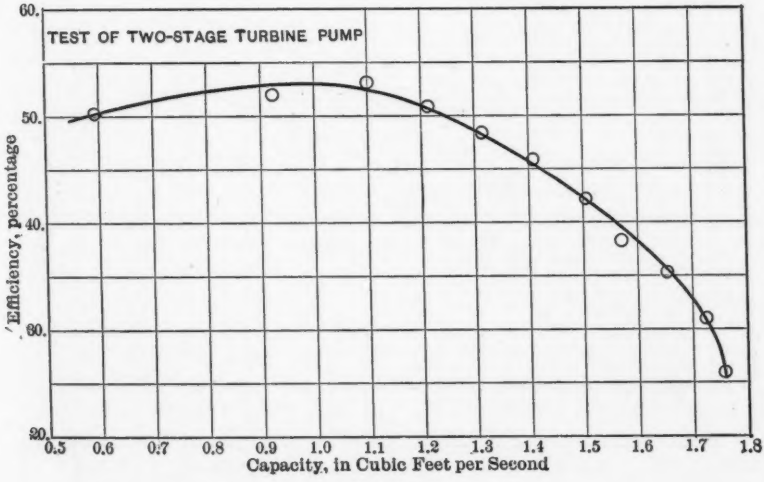



FIG. 4.

quantity of water discharged is measured. From these quantities the velocities in the suction and discharge pipes become known, and the total output of energy may be computed in the manner described in the test of the two-stage pump, as stated previously. When low velocities are used, the difference between the total energy and the useful work will often be small, particularly if the suction pipe is enlarged where the water enters it and the discharge pipe is enlarged where the water leaves that pipe. With the high velocities used in dredging, the difference between the total energy and the useful work is much greater; often the discharge level is practically that of the suction side, and the useful work consists in developing a high velocity and consequently great kinetic energy in order that material may be carried along with the water. It is evident, there-

Mr. Gregory.

fore, that, in the case of dredge pumps, the total-energy basis must be used.

It is customary to report tests of ordinary pumping plants on the basis of useful work, and tests of dredge pumps on the basis of the total-energy output. This should be kept in mind in comparing efficiencies.

The writer has tested large pumps, used for elevating water, which had efficiencies as high as 75% when based on useful work.

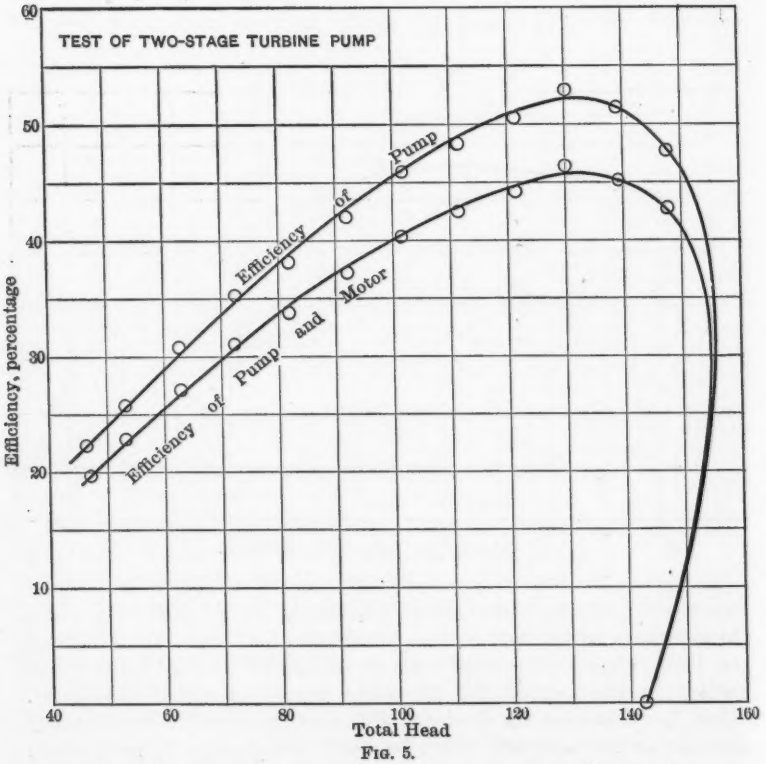



FIG. 5.

Such pumps are not at all common; they are the exception and not the rule. From 60 to 65% represents more nearly the average case, and it is not at all difficult to find examples which fall much below these figures.

Tests of pumps used in hydraulic dredging were made by the Mississippi River Commission in 1902 and 1903. The total efficiencies were found to range from about 57 to 68% in the various

cases. These results are very good, and will compare with those obtained from many centrifugal pumps using lower velocities. The pumps were large, and the diameters of the discharge pipes varied from 32 to 36 in. Mr Gregory.

H. F. DUNHAM, M. AM. SOC. C. E.—If the speaker is not mistaken, the author has failed to mention the size of the centrifugal pump or the diameter of the rotor. Dimensions and capacity are so closely related to the percentage of efficiency obtainable that it would be well to include them when possible. The speaker's rather limited acquaintance with centrifugal pumps and their manufacture does not coincide very closely with the author's experience. The manufacturer usually knows pretty accurately, from his own shop tests or published tests, the efficiency of the pumps that he puts upon the market, and, while now and then an anxious salesman or a man not anticipating any check upon his statements may be extravagant to the degree indicated, yet the speaker believes that generally, in the East, it would be difficult to find a manufacturer who claimed 50% for a small centrifugal pump. When the capacity is much increased—perhaps to a No. 7 or No. 8, in which the number indicates the diameter of the discharge, and the working head is not very great—there might be some assurance from reliable manufacturers of an efficiency approaching 50 per cent. It would be of interest to know whether the maker of the pump in question first put it out with that guaranty of efficiency, or whether the guaranty was made by some agent unacquainted with facts usually known to the builder, who was thus drawn into the discussion and led to "take chances" upon the result. The speaker recognizes a wide difference between ordinary oral "claims" for efficiency and the incorporation of such "claims" in the terms of a contract. Mr. Dunham.

PHILIP E. HARROUN, M. AM. SOC. C. E. (by letter).—The writer desires to correct a misunderstanding by Mr. Richards. The test of the unit was in no sense an effort to educate the engineering students of the University of California, but was simply a test of a piece of commercial apparatus for the purposes indicated in the paper. The result of this test, together with the results of other tests made by Professor Le Conte, will be published ultimately by the United States Department of Agriculture. Mr. Harroun.

All Mr. Dunham's inquiries are answered specifically in the text of the paper, with the exception of his question relating to the size of the rotor. Detailed prints showing the construction and dimensions have not been available at any time.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## A NEW GRAVING DOCK AT NAGASAKI, JAPAN.

### Discussion.*

By L. F. Bellinger, M. Am. Soc. C. E.

Mr. Bellinger.

L. F. Bellinger, M. Am. Soc. C. E. (by letter).—Mr. Hollyday states that practically no money has been spent for repairs on the body of Dry Dock No. 1, at the New York Navy Yard; but, as a matter of interest, it is well to note the fact that the entrance to that dock was practically rebuilt some years ago by P. C. Asserson, Civil Engineer, U. S. Navy. On account of quicksand, the old entrance to the dock began to bulge upward. The rebuilding consisted of an inverted granite arch. This work was completed about August 1st, 1888, the total cost being about $86 000.

The repairs mentioned as being novel by Mr. Hollyday were completed under his direction, therefore, it would be of considerable interest if he would give the Society a detailed account, especially as they pertained to the injection of cement into sand to serve as a cut-off for water percolation, a subject on which information has been requested in the technical papers without eliciting any replies.

* Continued from February, 1906, *Proceedings*. See October, 1905, *Proceedings* for paper on this subject by Naoji Shiraishi, M. Am. Soc. C. E.

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# PAPERS AND DISCUSSIONS.

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## THE POSITION OF THE CONSTRUCTING ENGINEER, AND HIS DUTIES IN RELATION TO INSPECTION AND THE ENFORCEMENT OF CONTRACTS.

### Discussion.*

By Albert J. Himes, M. Am. Soc. C. E.

Albert J. Himes, M. Am. Soc. C. E. (by letter).—It is a pleasure for the writer to express his appreciation of the kindly reception which has been accorded to a paper which, both in subject and in character, differs materially from those generally presented to the Society for discussion. He fully believes that the subjects discussed are of the most vital interest to all constructing engineers, and can be studied exhaustively with much profit. Mr. Himes.

Mr. Russell's suggestion that "the broad question of the proper interpretation of engineering specifications * * * should be brought up annually for discussion" is very pertinent, and is deserving of careful consideration.

The industrial development of the country has been so rapid that customs affording a sufficient basis for common law have hardly had time to mature; surely not time enough to meet the old English requirement that they shall have existed from "a time whereof the memory of man runneth not to the contrary." It should be the aim of the engineer, and especially of this Society, to work for the establishment of such customs, and thereby purge the profession of all

* Continued from February, 1906, *Proceedings*. See November, 1905, *Proceedings* for paper on this subject by Albert J. Himes, M. Am. Soc. C. E.

Mr. Himes. loose practices and slovenly methods which may lower it in public esteem or hinder it from becoming a stronger force in the social order.

The establishment of a court or "contract committee," as suggested by Mr. Smith, to pass upon disputed questions would be an ideal way in which to establish such customs. That is precisely the way in which the common law was originally developed, and is an eminently proper way in which to develop a common law that may be applicable to modern conditions. That such a court would have no legal status, is not material, for there is a large class of cases in which the parties only wish to be assured that they are treated fairly and according to custom. It is the suspicion of unfair dealing that breeds the larger number of disputes, and the decisions of such a court would be more satisfactory in their adjustment than the rulings of a court at law.

Although the decisions of the court would have only the force conferred upon it by the applicants, in time there would be established a series of precedents which could not be overthrown by the law itself.

Such a procedure is not without example, other than the original development of the common law. The British and North German Lloyds had a similar origin, in the association of vessel owners for the protection of their mutual interests, and the greatness of their success exceeds the wildest flight of the imagination.

An example of the work which such a committee might hope to accomplish may be found in the engineering custom of paying only for materials actually used in the work. The custom in vogue among builders and architects of measuring quantities according to various arbitrary rules is chaotic and illogical, and is distinctly inferior to the engineering method.

Mr. Aiken has mentioned some of the sophistries used by manufacturers in excusing their products. Such methods, to one who understands them, appear to be silly, but they cause lots of trouble among people who are unfamiliar with the business. Only an experienced man knows the value of experience, and it can hardly be expected that a dry-goods merchant will be interested in the phosphorus content of the steel for his new store building, or that a chief engineer who never saw a steel mill will take much interest in rail inspection.

Mr. Haring has related some of his troubles, and, perhaps, he at least will excuse the writer for referring to one of his own. There were large quantities of slope wall to build on three divisions, over one of which he had nominal control. The specification was impossible of execution, and he issued instructions to his assistants explaining what should be required. For this he was severely criti-

cised, it being held that any such "let up" would afford an excuse for ignoring the specification entirely. After the work had been in progress about six months, his chief took him to task for exacting such good work of the contractors, saying that the men in charge of the other divisions were not so particular. It is plain that, by using a little reason in the first case, good work was obtained, whereas, on the other divisions, in attempting the impossible, the result was a failure, and the work was as bad as it well could be. The solicitude of the chief for the welfare of the contractors was the cause of a change of management. Mr. Himes.

The opinion of Mr. Lovell, on the use of a blanket clause in the specifications, is commended to the profession. A man who does not know or cannot describe what he wants should get some one else to describe it for him.

Mr. Thompson emphasizes the need of uniformity of practice. This seems to be one of the aims of the United States Reclamation Service, and the writer has felt the need of it in his experience. The American Railway Engineering and Maintenance-of-Way Association is doing some excellent work in this direction, and its influence will be strongly felt in the profession.

Mr. Beahan's discussion has made very clear the meaning of a contract and the correct attitude of the engineer. His words should be studied with care. In them the young engineer may find more of value than in a whole library of technical books.

To Mr. Bixby, the writer is especially indebted for his kindness in giving to the Society some of his experience as an attorney in cases involving engineering work. His estimate of the value of a diary showing the progress of a piece of construction should be impressed upon every mind. He has also made it clear that an engineer is not a judicial officer, but that the value of his decisions rests on his expert knowledge and in his faithful obedience to the law which requires that his decisions shall be reasonable. In other words, his authority exists almost entirely because of his knowledge and integrity. If he is lacking in these, his decisions will not stand.

In summing up the discussion, the conclusion that seems to be most strongly impressed upon the mind is that, after having studied mathematics and the applied sciences, after having learned to run a transit and become an expert workman, if a man would attain eminence as an engineer, he must descend to the level of a newsboy and study human nature. He must begin at the bottom and seek to understand the ways of men, as individuals and as social units. He must acquire a knowledge of the laws of society and adjust himself so that he may move and act in harmony with its highest aims. Until he does this he is like a pebble in a pot-hole forced around and around by the rushing torrent. When he finally discovers his true

Mr. Himes. position, when he discerns his correct relations to other beings and his surroundings, then, like an atom in Nature's chaos, he may select his affinities, unite in harmony with others and crystallize into a bulwark of society against which the tide may surge and the storms may beat, but over which they will not prevail.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## THE ECONOMICAL DESIGN OF REINFORCED CONCRETE FLOOR SYSTEMS FOR FIRE-RESISTING STRUCTURES.

### Discussion.*

BY MESSRS. WILBUR J. WATSON, CLARENCE W. NOBLE, I. KREUGER, RICHARD T. DANA, C. A. P. TURNER, ERNST F. JONSON, LEONARD C. WASON, E. P. GOODRICH AND EDWIN THACHER.

WILBUR J. WATSON, M. AM. SOC. C. E. (by letter).—Many of the larger cities have building codes which prescribe certain assumptions which must be made in computing reinforced concrete building work, and some of them require that copies of the computations shall be filed with the city authorities. Under such restrictions, the engineer is not at liberty to exercise his own judgment as to the formulas which he shall use, but must select those which will give rational results and still comply with the requirements of the building code, which are often irrational. One of these sets of requirements is as follows: Mr. Watson.

First, that the ratio of the modulus of elasticity of steel to that of concrete shall be taken as equal to 12;

Second, that the stress in any fiber of concrete shall be assumed to be directly proportional to its distance from the neutral axis;

Third, that the unit stress in concrete, due to bending, shall not exceed 500 lb. per sq. in.;

* This discussion (of the paper by John S. Sewell, M. Am. Soc. C. E., printed in *Proceedings* for December, 1905), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.
Communications on this subject received prior to April 27th, 1906, will be published subsequently.

Mr. Watson.

Fourth, that the unit stress in steel shall not exceed 16 000 lb. per sq. in. under bending loads.

The writer does not wish to be understood as defending the foregoing requirements, especially the first two, which are shown by the author, and also by George H. Blakeley, M. Am. Soc. C. E., in his excellent analysis of the subject published in *The Engineering Record* of May 27th and June 3d, 1905, but is discussing the matter from the viewpoint of the practical designer who is compelled by law to conform to those restrictions. In proportioning the quantity of steel, the writer uses a value of 0.85 of the distance from the top of the beam to the center line of the steel reinforcement as the effective depth of the girder, as recommended by the author. The writer does not like the idea of using multiplied stresses in the analysis of reinforced concrete beams, as it seems to be more rational, and more consistent with the method of analysis used for other types of beams, to use the working stresses assuming the modulus of elasticity of concrete to be constant under the ordinary working stresses. It is often argued, in favor of complicated formulas for designing reinforced concrete beams, that the tests of beams show a greater strength than the more rational and simple formulas would indicate, but such is also the case in regard to the ordinary steel-plate girder. Most writers who deal with this subject place too much reliance on the ultimate strength of a reinforced concrete beam.

It is pretty well demonstrated by tests that, when the stress in the steel rods reaches a comparatively low value, cracks will begin to appear on the tension surface of the concrete. It seems to be the idea that it is safe to disregard this cracking of the concrete in tension, entirely on the supposition that, provided the stress in the steel does not exceed the yield point or elastic limit of the same, these cracks will close up on the removal of the load, and no harm will be done to the beam. Now, the writer is a skeptic on this point, and, until much more definite data are obtainable, relating to the cracking of such beams on their tension surfaces, and the consequent exposure of the reinforcing rods to corrosive influences, it would seem to be wise for conservative designers to use low unit stresses in the reinforcing steel, in order to reduce, as far as possible, the strain of the concrete in tension.

Granting that it is advisable to use a low unit stress in the steel reinforcing bars, there appears to be very little advantage to be gained in using a high-carbon steel, or, in many cases, a distorted bar. The only advantage that appears to be gained by the use of high-carbon steel is the increase in the factor of safety obtained, provided that such factor of safety be based upon the ultimate failure of the beam. If, however, the factor of safety be based upon

Mr. Watson.

the point at which damaging cracks occur in the tensile surface of the beam, the factor will be the same for soft steel as for high steel bars. It will be found that by using a low unit stress in the steel and by using small-sized bars in order to obtain a large adhesive surface, it is often unnecessary to use distorted bars, as conservative values of the adhesion of the concrete to plain bars will suffice to transfer the web stresses to the bars. The superiority of soft or medium steel bars over high carbon bars lies in the greater reliability of the former and the fact that they may be safely bent cold in the field. The writer is firmly of the opinion that when high carbon bars are used, as they very often are, they should never be allowed to be bent at all, as they are very likely to break in the bending, if bent cold, or to be improperly treated, if heated and bent. The writer knows of several cases where high steel bars have repeatedly broken while being bent for use in reinforcing concrete work. If, however, high carbon steel is used, and also high working stresses, then it will often be found necessary to use distorted bars, as in many cases the adhesion of the concrete to the steel will not then suffice to transfer the higher stresses. The writer is not quite convinced of the necessity of attaching web members rigidly to the horizontal bars. The method practiced by the writer has been to use vertical **U**-bars which are placed in the forms first, the horizontal bars are then placed upon them and are supported by them, the **U**-bars being hung at their upper ends upon a longitudinal bar supported by blocks placed upon the floor forms. In this way the vertical rods are drawn up tight against the horizontal bars and are thus enabled to transfer tensile stresses directly to the latter. As the **U**-bars are held by the concrete from slipping along the horizontal bars, the writer cannot see why this is not as good as a rigid attachment to the horizontal bars. The system is very convenient in the field. The writer agrees with the author that web members should be used in nearly all cases of beams, and especially when the beams and girders are placed and allowed to set before the floor slab is laid, which seems to be a common method of procedure.

Mr. Noble.

Clarence W. Noble, Assoc. M. Am. Soc. C. E. (by letter).—The writer has read this able paper with a great deal of interest. It is particularly opportune, as the use of reinforced concrete is becoming very general, before many of the theoretical points connected with its design have been definitely decided, and before engineering practice in this regard has been in any degree standardized. For example, there is in common use a bending moment formula which gives an ultimate value for a given beam 100% in excess of the value given by another formula also generally used, and both formulas are sanctioned by practice. The variation in practice regarding the use of shear bars is another case in point. It is to be hoped, therefore, that this paper will be very fully discussed.

Mr. Noble.

Some time ago the writer, by graphical methods, reached the conclusion derived analytically by the author, namely, that economical design requires that, unless prevented by other considerations, the steel reinforcement should develop the crushing strength of the concrete when its own elastic limit is reached. Just what percentage of steel is necessary to develop this crushing strength is a question on which opinions differ. A. N. Talbot, M. Am. Soc. C. E., found that in 1-3-6 concrete beams 60 days old the crushing strength of the concrete would not be developed by less than 1½% of mild steel or 1% of high-carbon steel. W. K. Hatt, Assoc M. Am. Soc. C. E., found that 2½% of mild steel did not develop the crushing strength of a 1-2-4 rock concrete beam loaded centrally. Edgar Marburg, M. Am. Soc. C. E., found that a beam reinforced with 1.19% of Ransome bars having an elastic limit of 58 000 lb. per sq. in. did not fail by the crushing of the concrete. These tests show allowable percentages of steel considerably in excess of those derived analytically by Captain Sewell. On the other hand, A. L. Johnson, M. Am. Soc. C. E., working analytically, reached a result slightly below those under discussion. Theory and practice here seem to part company. As the maximum of economy is attained in beams highly reinforced, this is a point concerning which investigation can be profitably continued.

Economy in the choice of materials is a matter which is pertinent to the subject under discussion. In designing roofs, for example, it is frequently found theoretically possible to use slabs much thinner than the 3-in. limit fixed by good practice. In such cases, using the 3-in. slab, if the reinforcement used is less than 0.5 of 1% of high-carbon steel it is advisable to use cinder concrete, as the material is cheaper and affords sufficient strength. The choice between the various forms of patented and unpatented reinforcing bars also resolves itself into a question of how much total elastic limit in a satisfactory form can be bought for a cent. If a given amount of tensile strength, together with the necessary bond between the concrete and steel and sufficient provision for shearing stress, can be supplied by plain bars at less expense than by patented bars, then, obviously, the cheaper bars should be used. This brings up a discussion of the nature of the bond between steel and concrete.

The most extensive series of tests of the union between steel bars and concrete, known to the writer, was made at the Massachusetts Institute of Technology.* The report of these tests has also been widely circulated by the patentees of a certain kind of deformed bar. A number of plain and deformed bars were embedded for various lengths in 1-3-6 concrete blocks. These bars were pulled out by direct tension from an Olsen testing machine. The bars

* *The Railroad Gazette*, September 18th, 1903.

extended entirely through the concrete, and observations were taken on the free end to determine the first slip. The tests on round and square plain bars of structural steel are shown in Table 1. Mr. Noble.

TABLE 1.—TESTS OF ADHESION BETWEEN PLAIN BARS AND CONCRETE.

| Size and kind of bar. | Depth embedded, in inches. | Adhesion, in pounds per square inch exposed to concrete. | Stress per square inch in bar. |
|---|---|---|---|
| ¾-inch, round | 24 | 271 | 38 400 |
| ¾-inch, square | 24 | 274 | 35 200 |
| ¾-inch, round | 31 | 255 | 42 200 |
| ¾-inch, square | 31 | 243 | 40 400 |
| ¾-inch, round | 36 | 219 | 42 200 |
| ¾-inch, square | 36 | 221 | 42 700 |

It will be noted, from Table 1, that in every case the bars slipped in the concrete at a point where the steel was strained to more than its elastic limit. This makes an obviously unfair test, for, when the bar begins to elongate, the entire load is taken off by the concrete immediately around the point where the bar enters it, and consequently the adhesion between the concrete and that portion of the bar farther within the block will not be stressed. The resultant action would be similar to that in tearing a piece of paper, which can withstand a considerable tensile stress applied uniformly over the sheet, but fails at once when the load is concentrated at one edge. Such an action shows very plainly in the tests given in Table 1, as the longer bars failed at considerably lower average adhesive stress per square inch than the shorter bars. This condition probably exists to an extent in tests made within the elastic limit of the steel, although it would never occur in a reinforced concrete beam under actual working conditions, as there the stress is applied gradually by the concrete acting on the bar, and the ends of the bar are unstressed at all times. Overlooking this fact, however, Table 1 would show that one can expect an adhesion between concrete and plain steel bars of more than 275 lb. per sq. in. Professor Hatt finds values varying from 636 to 756 lb. per sq. in., and states that, after the rod starts, from 50 to 70% of its original adhesion remains, due to the grip of the concrete. Bauschinger obtains values ranging from 570 to 640 lb. per sq. in. If experimental tests are of any value, an assumption of 250 lb. per sq. in. for adhesion is certainly conservative. This being the case, the statement made by the author that the sum of the horizontal components of the stresses in the web members on each side of the center of the beam should be sufficient to develop the strength of the flange reinforcement, can

Mr. Noble. only be justified as economical practice on the ground that the bond between the steel and the concrete below the neutral axis of the beam is unreliable. He must also consider the ability of the concrete to resist shear as worthless. The majority of engineers dealing with reinforced concrete will probably not agree with the author on these points.

J. W. Schaub, M. Am. Soc. C. E., talking before the students of the Armour Institute of Technology, compared experiments with rods embedded in concrete with those made with concrete pats allowed to set upon steel plates. He concluded that the adhesion between concrete and an embedded rod is due to two causes. The first is the formation of a slightly soluble silicate of iron having a cementitious value in tension of 22 lb. per sq. in. The second is the gripping effect of the concrete due to shrinkage during setting, which pushes particles of cement and sand into the minute unevennesses of the surface of the bar. The silicate of iron causes that portion of the adhesion found by Professor Hatt to be lost with the initial slip. Assuming either Hatt's or Bauschinger's values as correct, all the silicate can be dissolved out of the concrete, or can attach itself to mill scale instead of to the steel itself without reducing the adhesion to 250 lb. per sq. in. Evidently, therefore, this can be assumed as a safe ultimate value.

The advocates of deformed bars advance the argument that the lengthening of a bar under tension tends to decrease the diameter of the bar and thus relieve the grip of the concrete. Now, it is not at all certain that the lengthening of the bar within the elastic limit will cause a corresponding loss of diameter. Certainly, the tendency is to separate the molecules of steel forming the bar, and it is hard to see how this tendency can be transmitted from molecule to molecule along the length of the bar unless some separation actually takes place. But, assuming that the diameter is reduced correspondingly, and that a high-carbon bar having an elastic limit of 50 000 lb. per sq. in. is stressed from zero up to that limit, it would only be increased by $\frac{5}{2900}$ of its original length. A corresponding reduction of area would mean that the reduced radius would be 0.99914 of its original length, thus reducing the radius of a $\frac{1}{2}$-in. bar by 0.000215 in. and the radius of a 1-in. bar by 0.000430 in. If it be assumed that the concrete grips the bar with a pressure of only 250 lb. per sq. in., and that the modulus of elasticity of concrete is 2 400 000, it would only relieve the compression for a distance of 2 in. from the $\frac{1}{2}$-in. bar if the concrete should follow the receding steel for the entire distance of 0.000215 in. Evidently, there is no danger that the reduction in diameter of the bar will cause the particles of the concrete to withdraw from the interstices of the steel surface.

Mr. Noble.

A refusal to recognize the shearing value of concrete can only arise from the belief that when the beam has taken an appreciable deflection, so that the concrete below the neutral axis has been separated by minute cracks, this shearing value disappears. This is doubtless the case where such cracks occur, but, taking place as they do at points where the steel is stressed the highest, they occur at points of lowest shear, and, even here, unless the steel is loaded to more than its elastic limit, do not go above the neutral axis of the beam. Even if the beam is designed for a concentrated moving load, the concrete above the neutral axis near the middle of the span would be as well able to take the maximum shear coming on it as would the concrete in the full depth of the beam near the ends. Therefore, it would seem to be only necessary to provide vertical reinforcement for shear in excess of that which can safely be carried by the concrete.

It is the writer's belief that economical designs are best obtained by the use of a comparatively large number of small undeformed bars for horizontal reinforcement. This insures ample bond between the steel and the concrete for all but very short and deep beams. As the ends of the beam are approached, the flange stresses become of relatively less importance, and these bars are then, one or two at a time, turned up at an angle of from 30 to 45° into the concrete and continued along the top of the beam to the point of support, where they bond into the wall or adjacent beam. They thus serve successively as positive-moment bars, shear bars, and negative-moment bars, meeting in each situation the greatest need of the beam, and doing it always with a maximum of economy.

Mr. Kreuger.

I. KREUGER, ASSOC. M. AM. SOC. C. E. (by letter).—Mr. Sewell gives some very valuable suggestions for the design of reinforced concrete beams. The writer believes, however, that until more thorough knowledge of the properties of concrete is obtained, the straight-line formula is the most satisfactory one for computing reinforced concrete girders.

There is hardly a prominent engineer in Europe or America dealing with concrete who has not established a formula of his own, usually built upon an assumed variation in the stress-deformation curve of the concrete. The factors which influence this curve seem to be so many and of such a complex nature as to make hopeless the task of obtaining a result, true for all classes of concrete. While numerous observations as to the deformations of concrete under compression have been made in Europe and America, the widely different results obtained tend to make them rather confusing, and, under these conditions, the author's stress-strain curve seems to be an unwarranted refinement.

The simplicity of the straight-line formula, and the fact that it

Mr. Kreuger.

is accepted for the building laws of many prominent cities, are factors greatly in its favor. It seems to the writer, however, to be of secondary importance to establish the true stress-strain curve of the concrete in compression, as all tests show that this curve is quite different from the stress-strain curve of the concrete subjected to bending. This is not always clearly recognized, but the customary provision to calculate a higher value for bending compression than for direct compression is an admission of, and an allowance for, the errors of the present method of computing reinforced concrete girders.

Such evidence can also be found in the tests mentioned on page 652* where the steel was pulled apart, though the percentage of steel was more than twice the amount recommended in the table on page 634.*

If one insists upon computing concrete girders in a manner similar to that used for steel beams, and if one maintains the assumption that the tensile strength of concrete should be neglected, the results of the bending tests executed on reinforced concrete girders would lead to the assumption of a stress-strain curve following closely a rectangle. The diagram for such a curve would then have the appearance of Fig 7.

The writer, however, believes that, until more thorough tests have been made on this subject, the straight-line formula at present in use is the most convenient way for calculating reinforced concrete beams.

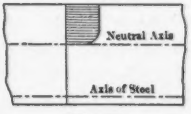


Fig. 7.

The conclusions to which the author comes, that for economical design as large a percentage of steel as the concrete will stand should be used, and that no steel should be put into the upper flange, seem to be thoroughly sound, and are probably in conformity with the experience of most designers.

Regarding T-beams, the author brings up the question of the flange width which should be counted on. The praxis on this point varies greatly. The building laws of several cities, notably Cleveland and Buffalo, allow a width of ten times the width of the beam. It is contrary to all authorities on this subject, however, to use such a large flange width, and the figure given by the author—three times the width of the beam—seems to be much more satisfactory. It is difficult, however, to see in what way the allowable flange width is influenced by the width of the beam, and it would seem to be more correct to make it dependent upon the length of the span. For certain cases where there is danger of buckling, the thickness of the slab may be the governing factor. It has been the writer's praxis to allow a total flange width of one-sixth of the length of the beam.

* *Proceedings*, Am. Soc. C. E., for December, 1905.

Mr. Kreuger.

The system of web reinforcement described by the author is a very interesting feature of the paper. It may be said that the value of web reinforcement has been clearly established, and most engineers agree upon this point.

Of the author's final remarks, the writer considers No. 6 particularly worthy of attention. If concrete girders were generally calculated as continuous, and the steel reinforcement arranged accordingly, a great saving could be made, and at the same time there would be a gain in safety.

Mr. Dana.

RICHARD T. DANA, ASSOC. M. AM. SOC. C. E. (by letter).—The author has taken the longest step, so far, toward placing the design of concrete structures on a strictly scientific basis. The mathematical work is admirable, and the deductions, in the main, seem to be accurate. The writer does not entirely agree with the author in placing the cost of steel at 3 cents per lb., as it would seem that 2½ cents would be a closer figure, bringing the average value of $p$ to 60. The author has designed his formula for ultimate strength. The writer is of the opinion that it is better practice to design for working stresses, for the following reasons:

1.—A very much smaller part of the stress-strain curve is brought into play, and to the stress-strain curve a close approximation may be made by a straight line, thus permitting the use of a straight-line formula.

2.—The factor of safety for concrete should, at times, be decidedly different from the factor of safety for steel in tension. If a beam is designed on the basis of the point of failure of the steel and concrete, or on the basis of the point of failure of the steel, namely, the elastic limit of the steel, and a percentage, say, 80, of the point of failure of the concrete when the beam is under vibratory loads, the concrete will be working under a disadvantage, as compared with the steel, and therefore the concrete will be overworked, which would result ultimately in weakening the beam. It would seem to the writer, therefore, to be better practice to design for the actual safe stresses of the two materials.

The formula worked out by the author is exceedingly ingenious, and is the simplest one known to the writer, having regard to rigidity of reasoning. In beam formulas, however, the writer prefers to use the method delevoped in the last few years in France by Coignet, Tedesco, and Maurel. The method replaces the steel in a section with a quantity of concrete equivalent to the area of the steel multiplied by $\frac{E_s}{E_c}$. The section, thus reduced to a homogeneous one, is referred to a neutral axis passing through the center of gravity, and the moment of inertia of the entire section is obtained on the basis of the concrete alone. This method results in extremely simple

Mr. Dana. formulas for rectangular T-beams, and is applicable to the rapid analysis of very complicated shapes. It is the only rapid method known to the writer whereby a hollow section of irregular area, with various arrangements of reinforcement, can be calculated accurately. The value of $N$, or the ratio between the coefficients of elasticity of steel and concrete, will, of course, vary for different conditions, and it seems to the writer to be essential, in any general formula, that $N$ be chosen by the designer for the special conditions of practice, and that it should be in shape to insert readily in the formula.

Concerning the question of web stresses, in the writer's opinion, the concrete beam is analogous, not to a Pratt truss, or to a Warren girder, but rather to a Howe truss. While the method of reinforcement given by the author is unquestionably excellent, and will produce a safe beam, it is believed by the writer that an equally safe and rather cheaper beam can be made with vertical stirrups spaced at distances equivalent to the depth between the centers of tension and compression, with special attention paid to what in a plate girder would be end stiffeners.

With the practical reasons, given by the author on pages 654 and 655,* for the use of stirrups or web members, the writer fully concurs, except in the argument based on the reconstruction of such beams in place. Where the heat from the fire has been so great as to dehydrate the cement, the steel is likely to have suffered greatly, and even if the concrete were replaced, the beam would probably not have anything like its original strength, particularly if cold-drawn wire or cold-twisted steel were used for the reinforcement.

The thanks of the engineering profession, as well as of this Society, are due to the author for this admirable paper.

Mr. Turner. C. A. P. TURNER, M. AM. SOC. C. E. (by letter).—While the writer has designed a great many buildings of reinforced concrete, and while, in every case where his instructions have been carried out, the resulting work has been stronger than represented by him, he will frankly state that though he has been able to design safe and satisfactory work at a low cost for construction, he regards it as impossible in the present embryonic state of knowledge of the properties of reinforced concrete to attempt successfully anything approaching a valuable general mathematical discussion and investigation of the economical design of reinforced concrete floor systems. This statement is made in fairness to Mr. Sewell in order that such criticism as the writer offers may be better understood, and that such theories as are presented with the criticism will be accepted in their true light, as a merely suggested explanation of observed facts.

It happens too often in a mathematical discussion that the

* *Proceedings*, Am. Soc. C. E., for December, 1905.



FIG. 1.—WAREHOUSE, N. W. KNITTING CO., SHOWING CONSTRUCTION WITH 5¼-IN. SLABS, 16 FT. 8 IN. BY 15 FT. 8 IN.



FIG. 2.—WAREHOUSE, N. W. KNITTING CO. TEST LOAD OF 900 LB. PER SQ. FT. ON 5¼-IN SLAB, 16 FT. 8 IN. BY 15 FT. 8 IN.

theorist starts out with an assumed premise, then proceeds to build an elaborate mathematical theory thereon, and forgets in his summing up that his reasoning, however accurate his mathematics, is, after all, based on the assumed premise rather than on fact. This seems to the writer to be the basis of the author's expressed belief that, in his short discussion, he has brought out the real principles of economic design. Mr. Turner.

The author's assumptions will be taken up in detail, in order to arrive at the value of his conclusions. First, he asserts that no extensive system of concrete floors can be economically designed without the use of rolled-steel beams or concrete ribs. Now, the writer's experience, in paying the cost of this work in labor and materials, is that where the panels are not greater than 25 ft. square, for a guaranteed test load of 200 or 300 lb. per sq. ft. over the full area, a plain slab without ribs costs less than one with ribs. In warehouse work, it is perfectly feasible to put up a building with columns at 16-ft. centers, with a floor of 7½-in. rough slabs, using no ribs at all, and test it with 800 lb. per sq. ft. without injury to the construction. Furthermore, it can be put up at less cost without the ribs, and will require less metal, as the load will travel more directly to the supports, instead of around a corner, as in the case where beams are used. This method of construction is outlined in Figs. 8 and 9.

Now, floor slabs are made anywhere from 5 to 25 ft. in span, and, on this basis, can a discussion, of the economic relations of the slab and ribs, which starts out by assuming a constant value for the thickness of the slab be regarded logically as of any value whatever? Aside from this little oversight, the author fails to realize that if beams or ribs are at 5-ft. centers, the rib centering costs just four times as much as if they were at 20-ft. centers. This, also, is an item which is not fixed by the problem in most cases, but by questions of economy only, and must appear in the discussion, if it be of any practical value whatever. Hence, the cost of centering, which the author assumes as a constant, is in reality a very variable one. Again, the floor system is but a part of the whole, and, as the same load can be carried to the footing more cheaply through one column than through two, this item enters into the discussion, if it be complete.

Now, in any physical research, a mathematical theory is of value only as it agrees with and explains the results of practical experiment and if the author's theory is tenable, as a general basis of economic design, it should fairly explain the results and facts developed in the course of practical work. Take, for example, the floor slabs illustrated in Plate XXV. The panel tested was 16 ft. 8 in. by 15 ft. 8 in., in which the slab was 5¼ in. thick with 1 in. of cheap strip filling on the top, reinforced with ⅜-in. round bars, at

Mr. Turner. 4-in. centers each way, each kept at an average of $\frac{3}{4}$ in. from the bottom of the slab. As these rods were kept close to the bottom right through, they could not be considered as reinforcing the slab over the beams on the top or tension side, as would be considered in the ordinarily accepted theory. The rods were long enough to go just over the top of the beams and were hooked at the end. A test load of cement in sacks of approximately 900 lb. per sq. ft. was

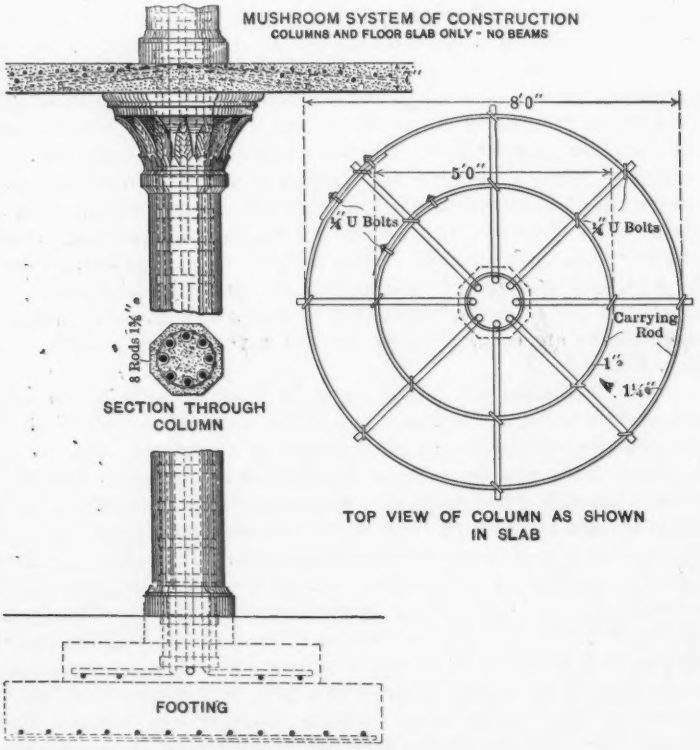



FIG. 8.

applied to the slab and kept inside the beam lines so as to give a straight shear load on the slab. The strip filling was a very weak mixture of lime, cement, and sand, so that it could have added little to the strength. Disregarding the strip filling and calculating the moment at $\frac{1}{8}$ $W\,L$, or, what is probably more nearly correct, $\frac{1}{10}$ $W\,L$, in the present case, distributed equally between the two systems of

rods, gives, in the author's formula: $M = h\,d\,a\,b\,t_s = 0.846 \times 4\frac{1}{2}$ in. Mr. Turner. $\times \frac{0.333 \text{ in.}}{12} \times 12$ in. $\times$ 40 000 = 50 760 in-lb. for the ultimate strength. Now, the moment of the load, $M = \frac{1}{10}$ (450 $\times$ 15) 16 $\times$ 12 = 129 600 in-lb.; in other words, the moment of the applied load is 2.6 times the yield point value of the steel, as indicated by the author's formula, leaving the dead weight to care for itself, or be carried by the cement. The actual deflection of the slab, under the

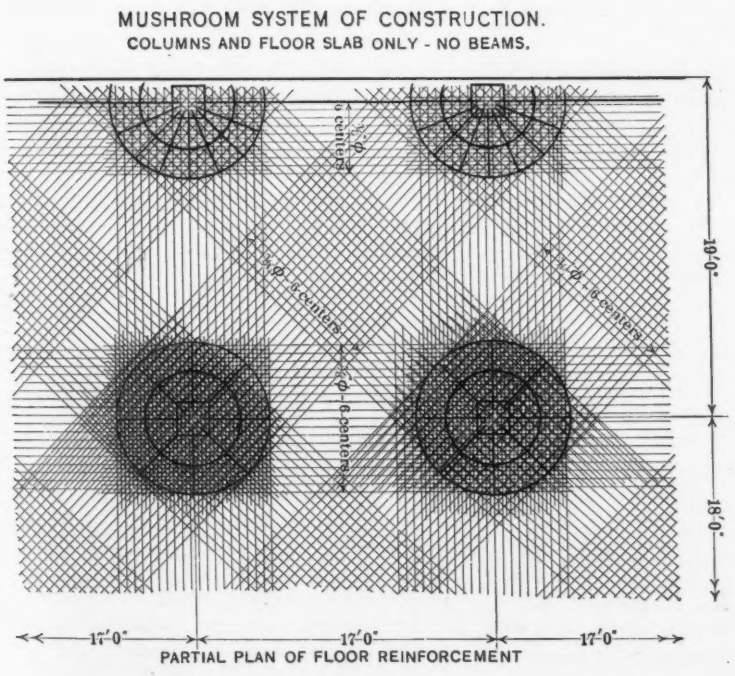



Fig. 9.

test load at the center, was only $\frac{5}{32}$ in., and it would require a deflection of $1\frac{1}{2}$ in., at least, even to crack such a slab. From this fact, it is a fair inference that the strength of the construction was at least from 700 to 800% of what might be expected from the author's economic theory; and either excessively strong concrete is being made or the author's theory is very weak indeed. It should be noted that the concrete tested was only about 7 weeks old, and, probably had not developed more than 70% of its ultimate strength,

Mr. Turner. due to the slow drying at that season of the year; further, that the deflection of the beams was $\frac{1}{16}$ in., leaving $\frac{3}{32}$ in. deflection of the slab between the beams.

Mr. Marsh, in his work on reinforced concrete, Part V, writes as follows:

"It may be that we are wrong from the commencement in attempting to treat it (reinforced concrete) after the manner of structural ironwork. * * * The molecular theory, *i. e.*, the prevention of molecular deformation by supplying resistances of the reverse kind to stresses on small particles, may prove to be the true method of treatment for a composite material such as concrete and metal."

It seems to the writer that the difficulty with the author's theory is in the fact that he is endeavoring to treat the dual material, as

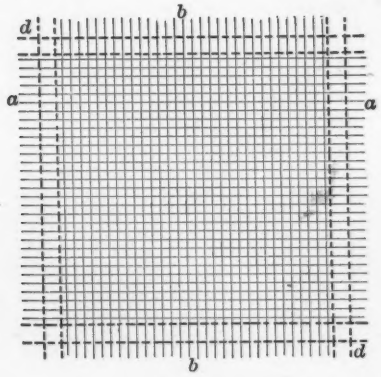



FIG. 10.

Mr. Marsh says, after the manner of structural ironwork. He practically starts out with the assumption that the concrete can be economically reinforced in one direction only, or assumes, following certain other writers, that where the reinforcement is applied in two or more directions, the same treatment holds; and that the stress has only to be divided between the various systems, and that otherwise, their joint action can be legitimately ignored.

Glancing now at Fig. 10, the following facts appear in evidence under any bending of the slab: The rods, *aa* and *bb*, the reinforcement, are in tension and along the diagonal lines; *dd*, the lower fibers, are also in tension. Now, these forces must be balanced by compression in the upper part of the slab. Where the reinforcement runs in one direction only, this stress is cumulative toward

the center, but where it is in two or more directions it may seemingly be carried largely by lateral arching. See Fig. 11. Mr. Turner.

Again, there is little exact knowledge as to how great an increase in strength may be obtained under the conditions that one compressive stress tends to balance the deformation of another. M. Considère's researches have thrown some light on this, and are, perhaps, an indication as to what may be accomplished along analogous lines. It may well be that the expert physicist may be able to devise an apparatus to measure the molecular stresses by thermo-electric means, as the writer has succeeded in doing in steel. For such investigation, a concrete of sand and cement only might simplify the problem.

Next consider the question of shear and bars with attached web members, or their equivalent, which the author seems to fancy because of his assumptions of an analogy between a concrete beam and a truss. In the experiments by A. N. Talbot, M. Am. Soc. C.

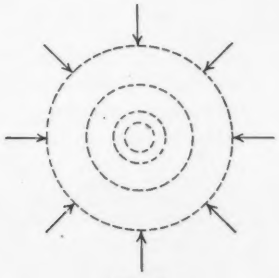


FIG. 11.

E., these bars indicated a strength of only 87% of that of plain bars of equivalent section, and, in view of their irregular shape, rough-sheared and nicked section, it is surprising that they did even as well as that. That good results have certainly been obtained with them, cannot be disputed, nevertheless, 60% of the strength that may be obtained with plain round bars and good work will pass muster anywhere.

As regards the use of shear members, the writer's experience would indicate that better results may be obtained without them, by simply tying in the skin of the beam or rib with a net. The idea of having the flange reinforcement all in the bottom of the beam, except at the center, is certainly rarely followed by those familiar with practical work, and the author's remarks, based on the assumption that the reverse is true, and his conclusions regarding the superior advantages of the attached web member bar, from the fire-proof standpoint, are not substantiated.

Mr. Turner.

Comparing the construction by the manufacturers of the attached web member bar with construction where plain bars are used, and referring to the warehouse of the Farwell, Ozmun, Kirk Company at St. Paul as a typical example of the former type, and the warehouse of the Minneapolis Paper Company as an example of the latter, the following tests offer a practical method of judging these claims. In the warehouse of the Farwell, Ozmun, Kirk Company, for the panel tested, the columns were at 13-ft. centers along the main girders, and at 16-ft. centers along the carrying beams, which were spaced at 5.5 to 6.5-ft. centers, and the slabs were about 7 in. thick. The test load was 78 tons of pig iron over one beam, which caused a deflection of $\frac{1}{64}$ in. In the warehouse of the Minneapolis Paper Company the panels were 15 ft. 4 in. by 21 ft. 6 in.; the slabs were $6\frac{1}{2}$ in. thick, over the full panel, with 1 in. of strip filling made of weak mortar; the reinforcement was $\frac{3}{8}$-in. round rods, spaced at an average of 6 in. from center to center each way; the beams ran from column to column in each direction only; the test load was 110 tons (shear load) on the slab, and, later, 50 tons were added to test a 12 by 16-in. beam with 21 ft. 6 in. span. The slab reaction on the beam would be approximately 70 tons. The deflection of the beam was practically inappreciable. Now, if, as above noted, $\frac{3}{8}$-in. rods with an average centering of 6 in. can carry on a $6\frac{1}{2}$-in. slab 110 tons to the beams, at 15 ft. 4-in. and 21 ft. 6-in. centers, the floor slab in the St. Paul warehouse, if the attached web member bar is any good, ought to distribute the load over at least three beams, so that this test was a little greater than the load the floor was designed to carry—500 lb. per sq. ft.—while, in the case of the plain bar design, there was double the load, and on a span one-third longer than that of the building of the Farwell, Ozmun, Kirk Company. There seems to have been in the slab approximately an equal weight of metal reinforcement per square foot in each case, and also per linear foot in the beam, though, in the plain rod design, the clear span of the slab was nearly three times as great, while the beam carried twice the load and was one-third longer in span. Upon such a showing, the attached web member bar would be entitled to rather a scant consideration, if this illustration is a fair one. Figs. 1 and 2, Plate XXVI, show some tests at the warehouse of the Minneapolis Paper Company.

The basis of the author's belief in the web member bar or its equivalent will now be examined critically. He states that he analyzed the web stresses by analogy with a Pratt truss, and, later, at the War College, further study made it apparent that the double-intersection Warren girder was a better analogy. Admitting, for the sake of argument, that it is permissible to draw valuable conclusions from truss construction relative to reinforced concrete beams, ac-



FIG. 1.—WAREHOUSE, MINNEAPOLIS PAPER CO. TEST LOAD OF 11 TONS ON 6½-IN. SLAB, 15 FT. 4 IN. BY 21 FT. 6 IN., CENTER TO CENTER OF BEAMS.



FIG. 2.—WAREHOUSE, MINNEAPOLIS PAPER CO. TEST LOAD OF 160 TONS ON 860 SQ. FT. COLUMN SPACING 15 FT. 4 IN. AND 21 FT. 6 IN., LONGITUDINALLY AND TRANSVERSELY, CENTER TO CENTER.

cording to the author's belief, the Pratt truss was a good analogy and the double Warren girder a better one, but, if an opinion is to be formed in this questionable way, engineers should obtain the best possible analogy. Taking the author's example, the case of the uniform load, and considering an analogy with an inverted parabolic bowstring or deck truss, the reinforcement is of constant section, as recommended by him, the web stresses are all compressive, and the curved reinforcement seems to be ideal in this respect, doing away with his multiplicity of relatively small and bothersome web members, effecting thereby a theoretical economy of 30% of the metal and 75% of the trouble in handling and placing it. This analogical theory, it will be noted, is for uniform loads. There remains, therefore, to treat any combination of live loads in a similar manner for the simple beam. Still proceeding on the author's recommendation of a constant tension chord section, as the compression chord of concrete is constant, one should seemingly look for a suitable analogy in that type of truss which economically discards diagonal panel web members, while complying with the

Mr. Turner.

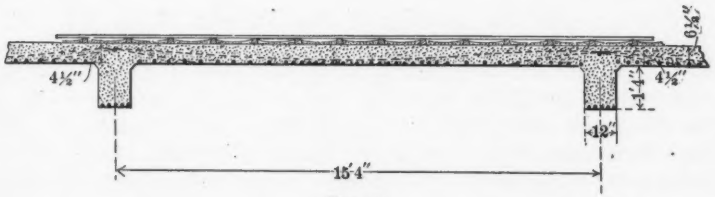



FIG. 12.

above fixed conditions, and this type is evidently represented in the Bollman truss. While, in steel construction, the conditions noted bar it from economical use, with these fixed, it possesses quite a marked advantage over reinforcement planned on the Warren girder order, combined with a dissemination of steel through the concrete and ease in placing it that should be apparent to those having practical experience in this line.

An example of the failure of the theory as applied to a slab which is nearly square has been given, and now the author's formula will be applied to the rectangular slab tested at the warehouse of the Minneapolis Paper Company, 21 ft. 6 in. by 15 ft. 4 in., from center to center, beams 12 in. wide, load 860 lb. per sq. ft., distributed over nearly 13 by 20 ft. in the center of the slab, as shown in Fig. 12.

| | | |
|---|---|---|
| Weight of construction..... | 90 | lb. per sq. ft. |
| Live load..... | 860 | " " " " |
| Total ..... | 950 | " " " " |

Mr. Turner. Using Mr. Dunn's well-known formula for distribution over rectangular slabs, with continuous reinforcement:

$$M_c = \text{Moment over support} = \frac{W\ B}{12} \times \frac{L^4}{L^4 + B^4},$$

$B$ being breadth, and $L$ length of slab. Therefore:

$$M_c = \frac{12\,350}{12} \times 15 \times 0.8 = 12\,000 \text{ ft-lb.} = 144\,900 \text{ in-lb.};$$

$d = 4\frac{1}{2}$ in.; $h = 0.846$; $t_s = 40\,000$.

$M = h\ d\ a\ b\ t_s = 0.846 \times 4.5\ (0.44) \times 40\,000 = 67\,000$ in-lb. = the calculated ultimate strength, while we have tested it to 2.2 times this amount with a deflection of $\frac{1}{1000}$ of the span, and could certainly apply more than 3 times this load before final failure. It should be noted that the value of $a$ used is the average section, the bars being spaced closer together at the center of the slab, in this particular design, and is taken as double for the lap of the rods in the adjacent panel. One would suppose that this arrangement would show greater stiffness than that first outlined, but a test does not seem to bear out the inference, or, at any rate, to give it a positive standing.

Next, consider the question of the character of the test. Was the loading such that the conclusions are warranted? Was there any considerable arching, and to what extent could the surrounding construction distribute the load? When the ratio of the depth of the slab to its span is only 1 to 8 or 10, as in the building of the Farwell, Ozmun, Kirk Company, the slab can distribute a very material part of the load over adjacent beams, but where this ratio increases from 1 to 8 or 10 to 1 to 25 or 35, the stiffness being approximately as the cube of the span, this amount would be but $\frac{1}{15}$ to $\frac{1}{25}$ of the former, where the ratio is only 1 to 8 or 10, perhaps from $2\frac{1}{2}$ to 4%, calculating this action in the former case, the St. Paul test, as great as 60 per cent.

Now, as to the question of the arching of the load from beam to beam, and reducing the load carried by the slab, it may be stated that the sacks were piled with especial reference to reducing this action to a minimum. With a deflection so small, this action, in any case, would be slight, perhaps reducing the calculated moment less than from 5 to 8%, which might be estimated for a sand or grain pile of these dimensions. It may be fairly said of the load that it is similar to loads that would be applied in use in the building, and that the slab load was piled inside the beam lines to give a straight shear load on the slab. Again, tests have been made on slabs with white lead in kegs, piled so that there was no arching, and the calculated strength, by the formula noted, did not agree more closely with the practical results than in the foregoing instances.

Referring now to the author's conclusions as to the economic

Mr. Turner.

relation of the cost of the concrete and steel, and, taking in this case a plate girder for analogy, it is considered conservative to disregard the web resistance to bending in a plate girder, just as in the concrete beam the web resistance of the concrete below the neutral line is disregarded. Now, according to general practice, it is calculated that the compression flange should equal the tension flange in cost, that the section of the flanges and consequent cost decreases with the increase in depth, and, by principles of maxima and minima, one ordinarily tries to prove the total cost a minimum when the costs of the web and flanges are equal.

Now, vary the problem by making the tension flange of a special grade of steel and the web and compression flange of common steel, as before, and write the moment equation thus:

$$M = h\ d\ a\ b\ t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (A)$$

in which $h\ d$ = the lever arm, or area $a$ of the bottom flange, and $t$ = the unit of tension. The variable quantities of the two different kinds are:

1.—The special grade of steel in the bottom flange; and

2.—The common steel in the web and top flange.

Now let $p$ represent the ratio of the unit costs of the two grades of steel and let $x$ equal a quantity proportional to the sum of the costs of the variable elements, and substitute for $a$ in this equation its value from Equation A, and it can be shown by the author's method that the total cost is a minimum when the cost of the special steel in the bottom flange equals the cost of the other three-quarters of the girder, that is, the common steel web and top flange. It should be noted that the assumed variation of the web and compression flange with the depth is identical with that assumed by the author in the case of the concrete beam.

Taking the first slab illustrated, reducing the concrete, and increasing the steel until the cost of each is equal, $3\frac{1}{2}$ in. is obtained as the depth of the concrete over the steel, and this on a span of 16 ft. 8 in. from center to center. As the steel is medium, $h$, according to the author's determination, equals 0.85, so that the effective depth, $h\ d$, equals $3.5 \times 0.85 = 2.97$ in., and the ratio of depth to span is as 1 to 65. These would seem to be rather attenuated dimensions to support a load of 900 lb. per sq. ft.; strangely enough, there does not seem to be an excessive percentage of steel, judged by his standards. Again, take the case of a simple beam 10 in. wide and 15 in. deep, the cost of the concrete above the steel is 22 cents, and 22 cents' worth of steel at $1\frac{3}{4}$ cents per lb. in place for plain bars equals $12\frac{1}{2}$ lb., or 3.75 sq. in. This corresponds to 2.75% reinforcement, nearly twice the maximum percentage necessary to develop the strength of the concrete by the author's computation.

Mr. Turner. While, from the engineer's standpoint, the writer can see but little opportunity for the use of this economic theory, from the standpoint of the vendor of reinforcement, if he can but convince the purchaser of its accuracy, the commercial possibilities in this line would seem to be very attractive. This commendable feature of the theory, combined with its apparent plausibility, would readily deceive anyone failing to note the confusion of constants and variables involved in the assumptions on which it is based.

The writer will now examine the assumptions under which the value of $h$ was determined a constant, and see how the author proceeds to fill these conditions in his economic theory. These conditions are that the steel and concrete are each worked to a definite and constant allowable limit. Now, in his economic theory, he proposes to vary $d$ and $a$ to balance a constant moment, $M$, but, arbitrarily, to keep $h$ and $b$ constants. The writer will start with a depth less than the economic depth and double it, and note at these extremes, under the author's assumptions, the variation of the working stress of the concrete. For the shallow beam, the concrete can be worked, of course, only to its safe working stress. When $d$ is doubled, the total compressive stress on the compression chord (the concrete) is cut in two, $b$ and $h$ remaining constant; by the author's economic theory, the area carrying this stress is doubled, making the working unit stress for the concrete, in the second case, only one-fourth of what it was in the first; in other words, according to the author's assumptions, he compares the economic relations of the steel and the concrete on the basis of a rational and fixed working stress for the steel and, as it happens, an actual variable (within the narrow limits of 300 or 400%) working stress for the concrete. This appears to be rather severe on the concrete, as indicated by the practical example of the slab. Upon such a basis of computation, it is hardly surprising that the author concludes that his theoretical economy, based on relative costs, is not attainable. He also notes that his discussion of minimum cost does not contain the ratio between the allowable maximum stresses in the two materials, but fails to note that this ratio, which should be fixed in a rational discussion, is an extremely variable one as involved in the equations from which he essays to draw his conclusions.

The writer, in his remarks, thus far, has not questioned the author's assumption of a constant section of reinforcement from the economic standpoint. Now, for a simple beam, where the moment varies from zero at the end to $\frac{1}{8}\ W\ L$ at the center, the need of the maximum section for the full length is not apparent. In the Moulton Jordon garage there were some short-span girders of reinforced concrete, 42 ft. from out to out, in which the writer considered that there was a very decided economy in designing them with a variable

flange, as he would have done if they had been steel. This saving, of course, would increase largely with the increase in span. Mr. Turner.

In ordinary floor systems, however, there is the general problem of a series of spans, and the question of the relative economy of continuous *versus* simple beams at once arises. As it is impracticable to vary the section of concrete along the length of the beam, and as the maximum moment for the continuous beam for a uniform load is approximately only two-thirds of that for the simple beam (calculating for an intermediate span), the continuous construction should result in a material saving in concrete.

Considering now the steel reinforcement: The moment at the support is double that at the center of the span, and of the opposite sign. Now, the rods are rolled of constant section, and, if they are carried from the tension flange at the center to the tension flange at the support and lapped into the next beam, there would be required, approximately, one-third the section for half the length and two-thirds the section for the remainder that would be required for the simple beam construction, or half the metal required in the simple beam with constant section of reinforcement. With this arrangement, there is the condition that the maximum flange reinforcement is required at the point of maximum shear, that the moment decreases rapidly from the support toward the point of contra-flexure, allowing this main reinforcement to drop sharply downward without weakening the construction, thus placing the main section of metal in a position to carry the entire shearing strain, without counting on the concrete or depending on the questionable amount of adhesion that may be obtained between the concrete and small and stubby web members.

This simple bend in the bars gives them an anchorage in the concrete which, from the writer's experience, appears to discount any form of nicked-section mechanical bond yet invented.

Owing to the fact that the moment at the center is only half that at the support, the question of reducing the concrete further by reinforcement of both flanges at the support, for part of the length only, should be considered, if the economic theory be complete. This method is followed by the writer.

Bad work, in one instance, executed by an incompetent contractor, on a footing, gave the writer an opportunity of judging the amount of distortion a connection of this character would stand, and he was not a little surprised to be forced to conclude that it could stand, if anything, as great an amount of distortion, without material injury, as could be expected from a structural steel frame with standard riveted connections of the web of the beams to the columns. Such reinforcement is more satisfactory from the standpoint of resistance to lateral or vibratory forces.

Mr. Turner. The fewer joints there are in the concrete, the more uniform it is in strength; and any method of placing it piecemeal, as observed by the author to be done frequently, cannot be too strongly condemned. The cement is that part of the composite material which gives it its strength, and, to the largest extent, its fire-proof properties, and anyone who possesses the temerity to follow the author's suggestion of using a cheap concrete for the lower half of a beam, whether with the attached web member bar or any other, is, in the writer's judgment, industriously looking for trouble rather than economy.

In conclusion, it is safe to assert that no one has a higher respect for true theoretical economy than the busy engineer of construction. This brand of theoretical economy is attainable, and is based on a complete and accurate statement of all the facts entering into the problem. That brand which is not attainable, he immediately concludes, is based either on an incomplete and defective statement of the conditions of the problem, or on inadmissible assumptions regarding them.

Mr. Jonson. ERNST F. JONSON, ASSOC. M. AM. SOC. C. E. (by letter).—There is one point in Mr. Sewell's paper to which the writer begs to call attention as not being quite correct.

The author takes the depth of the axis of the horizontal reinforcement below the top of the beam as a basis for his shear computation, instead of the depth of that axis below the resultant or centroid of the compressive forces.

The following proposition is true of all beams:

The total shear on any one cross-section of a beam is equal to the average unit shear at the neutral axis, multiplied by the width of the beam at the neutral axis, multiplied by the distance between the resultant of the compressive forces due to the bending moment and that of the tensile ones.

$$S = s\ b\ f.$$

Where $S$ = the total shear on the cross-section;
$s$ = the average unit shear at the neutral axis;
$b$ = the width of the beam at the neutral axis; and
$f$ = the distance between the resultants of the compressive and tensile forces.

The demonstration of this proposition is as follows:

Let $p$ = the longitudinal unit stress due to the bending moment;
$R$ = the resultant of this stress on each side of the neutral axis;
$M$ = the bending moment; and
$a$ = the distance from the neutral axis to the extreme fiber.

Mr. Jonson.

It is known that the shear at the neutral axis is equal to the first differential coefficient of the total longitudinal stress due to the bending moment on one side of the neutral axis.

$$s\,b = \int_{x=o}^{x=a} \int_{z=o}^{z=b} \frac{dp}{dy}\, d\,x\, d\,z \ldots\ldots (I)$$

Hence,

$$s\,b = \frac{d\,R}{d\,y} \ldots\ldots\ldots\ldots\ldots\ldots (II)$$

It is also known that the total shear on the cross-section is equal to the first differential coefficient of the bending moment.

$$S = \frac{d\,M}{d\,y} \ldots\ldots\ldots\ldots\ldots\ldots (III)$$

And, since $M = R\,f$,

$$\frac{d\,M}{d\,y} = \frac{f\,d\,R}{d\,y} \ldots\ldots\ldots\ldots\ldots\ldots (IV)$$

Hence,

$$S = \frac{f\,d\,R}{d\,y} \ldots\ldots\ldots\ldots\ldots\ldots (V)$$

By substitution, according to Equation II,

$$S = s\,b\,f \ldots\ldots\ldots\ldots\ldots\ldots (VI)$$

The formula for the maximum unit shear in a reinforced concrete beam will then be:

$$s = \frac{S}{b\,f} \ldots\ldots\ldots\ldots\ldots\ldots (VII)$$

And the formula for the stress, $t$, on the 45° diagonal reinforcement in one unit of length will be:

$$t = \frac{S}{f\sqrt{2}} \ldots\ldots\ldots\ldots\ldots\ldots (VIII)$$

It seems to the writer that a sharp bend at the junction of the diagonal and longitudinal reinforcements should be avoided, as it tends to produce an excessive compressive stress in the concrete at that point; and that a round bend would be better. If 1 000 lb. is allowed on the concrete and 16 000 lb. on the steel, the radius of this bend would be, approximately,

$$r = \frac{14\,A}{n} \ldots\ldots\ldots\ldots\ldots\ldots (IX)$$

Where $A$ = the area of the diagonal and $n$ = the width of the same. For round rods, this would make about

$$r = 10\,d \ldots\ldots\ldots\ldots\ldots\ldots (X)$$

Where $d$ = the diameter of the rod.

In this case, however, the stress in the diagonal would be about 40% greater at the lower end of the bend than at its upper end, so

Mr. Jonson. that, instead of Equation VIII, the following formula would express the stress in the 45° diagonal reinforcement in one unit of length:

$$t = \frac{S}{f} \qquad \text{(XI)}$$

Mr. Wason. LEONARD C. WASON, M. AM. SOC. C. E. (by letter).—The writer was considering the submission of a paper intended to draw out a discussion leading to the adoption of a simple formula for general use in designing reinforced concrete beams, when Captain Sewell's paper appeared, therefore this discussion is submitted partly as a discussion of his paper, instead of as an independent paper. Its object is to show that sufficient data are now available to determine an accurate formula (accurate within allowable limits of variation) for general use in designing beams of rectangular or T-section, and to emphasize the fact that the best results are obtained by solving for the working instead of the ultimate strength. Therefore this is not exclusively a discussion of Captain Sewell's paper. It is hoped that all those whose formulas are compared herein, and many others, will contribute to the discussion. There are probably at least ten formulas in use besides those mentioned. The writer has discussed the subject chiefly from its commercial aspect, and has purposely omitted the more technical points relating to the disagreement in results, leaving these to be discussed by the professors, who are much better able to do so.

The need of a generally accepted method has been forced upon the writer through competition. In several cases where architects have specified spans and floor loads, and have left the design entirely open to the bidders, work has been lost because competitors have put in lighter designs. In other cases, where a bid has been submitted, accompanied by plans, and, later, the designs have been submitted for review by a consulting engineer, the cost has been increased by more than 10%, due solely to a difference in the formulas. By reference to Table 2, a summary table of comparison, it will be seen that if the work had been designed by the method proposed by the writer, and submitted to an engineer to be checked by the author's formula, the cost would have been appreciably increased, because of the much lower moment of resistance for the same section of beam. Yet structures costing many millions of dollars have been designed by the formula proposed, competition has proved it economical, and the experience of fifteen years has proved it to be safe. There is a general and simple method for designing wooden and steel beams; why should there not be one for reinforced concrete?

The general form of formulas, Equation 0, of Captain Sewell's paper, $M = u\,d\,A\,f$, is correct. The only factor about which there can be much discussion is the value of $u$.

Mr. Wason.

The formulas which follow—proposed by nine writers—are based on different assumptions, all of which, from certain experiments, appear to have solid foundations. All are based on the same fundamental conditions, namely:

1.—All tension is carried by the steel;
2.—All compression is carried by the concrete;
3.—There is a perfect bond or union between the steel and concrete within the limits of the stresses used;
4.—The effects of shear are omitted, and failure is due to flexure only;
5.—There are no initial strains, and the same examples solved by each, using the same constants, ought to give results directly comparable.

The formulas of various writers are reduced to the same general form, and two examples (one a beam and the other a slab) are solved, first, using the same constants for all; secondly, using the constants proposed by each individual writer. The results are summarized in Table 2.

Assume a rectangular beam: span, 14 ft.; width, 12 in.; depth to center of reinforcement, 12 in.; total depth, 13½ in. Find the maximum moment of resistance, load uniformly distributed, area of steel, and neutral axis.

Assume, also, a flat slab: span, 8 ft.; width, 12 in.; depth, 4½ in.; depth to center of reinforcement, 4 in. Find the ultimate moment of resistance, load, area of steel, and position of neutral axis.

### Values of Constants, and Definition of Symbols.

Broken-stone concrete. Mixture 1:3:6. Age 30 days.

| | | |
|---|---|---|
| $E_c = E_t$ | = modulus at working stress | 3 000 000 |
| $E_s$ | = modulus of steel | 30 000 000 |
| $c$ | = ultimate compression in concrete | 2 000 |
| $t$ | = ultimate tension in concrete | 200 |
| $f$ | = elastic limit of steel | 50 000 |
| $f_1$ | = working stress in steel | 16 000 |
| $c_L$ | = working stress in concrete compression | 500 |

$M$ = moment of resistance of section of beam, in inch-pounds;
$W$ = total uniformly distributed load on beam, in pounds;
$E_s$ = modulus of elasticity of steel;
$E_c$ = " " " " concrete in compression;
$E_t$ = " " " " " " tension;
$f$ = fiber stress in steel, in pounds tension per unit of area;
$c$ = compression in outer fiber of concrete, in pounds per unit of area;
$t$ = tension in outer fiber of concrete, in pounds per unit of area;

Mr. Wason. $A$ = area of steel, in square inches;
$p$ = ratio of area of steel to cross-section of beam.
$n = \frac{E_s}{E_c}$;
$b$, $d$, $h$, $x$, $y$, $v$, $e$, see Fig. 13;
$z$ and $u$ are ratios of $d$ or $h$;
$l$ = span of beam, in inches;
$V$ = distance from top of beam to center of gravity of compressive stresses.

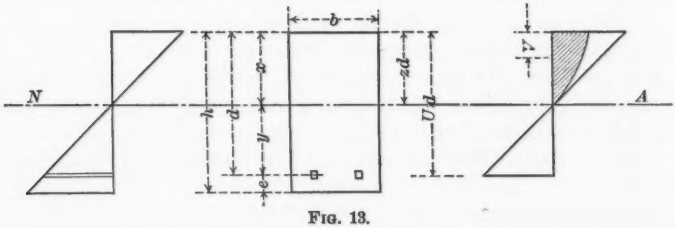



FIG. 13.

*1.*—The formula proposed by the writer is quite simple, and experience has proved that structures designed by it will carry their calculated load with the desired factor of safety. It assumes the neutral axis half way from the top of the beam to the center of the steel, and the center of gravity of the compressive stress at one-third of the depth from the top to the neutral axis; the compression area is confined to the upper third of the beam. The elastic theory is involved by the values selected for the working stresses of the steel and concrete, and by seeing that the areas of each are sufficient for the stresses used.*

$$A = \frac{b\,d\,c}{3f};$$

$$M = \frac{5}{6}\,d\,f\,A;$$

External moment, load uniformly distributed $= \frac{W\,l}{8}$.

Therefore,

$f = \frac{W\,l}{6\frac{2}{3}\,d}$, for a beam supported at its ends and uniformly loaded.

In any given case, the load and span are known. Select a convenient figure for the depth of the beam or the stress in the steel, and solve for the other unknown quantity.

*For a full demonstration see *Transactions*, Am. Soc. C. E., Vol. XLVI, 1901, p. 102; or *Engineering Record*, September 21st, 1901, p. 272.

Mr. Wason.

*Example of Beam:*

$$A = \frac{b\,d\,c_1}{3\,f_1} = \frac{12 \times 12 \times 500}{3 \times 16\,000} = 1.5 \text{ sq. in.};$$

$$M = \frac{5}{6}\,d\,f\,A = \frac{5}{6} \times 12 \times 50\,000 \times 1.5 = 750\,000;$$

$$W = \frac{750\,000 \times 8}{14 \times 12} = 35\,714.$$

*Example of Slab:*

$$A = \frac{12 \times 4 \times 500}{3 \times 16\,000} = 0.5;$$

$$M = \frac{5}{6} \times 4 \times 50\,000 \times 0.5 = 83\,333;$$

$$W = 6\,944.$$

There is no change in constants necessary.

*2.*—W. K. Hatt, Assoc. M. Am. Soc. C. E., has evolved an elaborate formula for flexure.* In the form here given, it applies to rectangular beams which do not fail by shearing. The stresses in the concrete are assumed to follow a parabolic curve. The formula gives the load at the first visible crack in the concrete on the tension side. This load, according to tests by Professor Hatt, is about 20% less than that of ultimate failure.

Let $h\ z$ = the distance from the compression face to the neutral axis;

$h\ u$ = the distance from the compression face to the center of gravity of the reinforcement;

$p$ = the ratio of the area of the steel to that of the total cross-section of the beam;

$f$ = stress at the elastic limit of the steel.

$p$ and $u$ are in the control of the designer; $n$ is fixed for the given materials and working stresses.

After a crack has formed, the neutral axis is located by the formula:

$$\frac{2}{3}\,z^2 = p\,\frac{E_s}{E_c}\,(u - x);$$

$$c = \frac{3\,p\,f}{2\,z};$$

$$M = b\,h^2\left[\frac{5}{12}\ c\ z^2 + p\,f\,(u - z)\right];$$

or, in a simpler form, where the expression in the bracket is represented by the constant, $K$,

$$M = b\,h^2\,K.$$

* *Engineering News*, February 27th and July 27th, 1902; and *Journal* of the Western Society of Engineers, June, 1904.

Mr. Wason.

For given conditions, a table is made for $K$, in order to simplify the application of the formula; or diagrams of the equation may be made and used. Professor Hatt states that, in his judgment, one-third of the amount at the first crack is the safe working moment of resistance. This would give a factor of safety, on the ultimate strength, of about $3\frac{1}{4}$.

*Example of Beam:*

$$p = \frac{A}{b\,h} = \frac{1.5}{12 \times 13.5} = 0.0092;$$

$$A \text{ (assumed)} = 1.5 \text{ sq. in.};$$

$$u = \frac{12}{13.5} = 0.9;$$

$$n = \frac{3\,000\,000}{200 \div \frac{1}{1\,000}} = 15;$$

$$\frac{2}{3} z^2 = 0.0092 \frac{30\,000\,000}{3\,000\,000} (0.9 - z);$$

$$z = 0.29;$$

$$C = \frac{3 \times 0.0092 \times 50\,000}{2 \times 0.29} = 2\,379;$$

$$M = 12 \times 13.5^2 \left[\frac{5}{12} \times 2\,379 \times 0.29^2 + 0.0092 \times 50\,000\,(0.9 - 0.29)\right]$$

$$= 795\,959;$$

$$W = \frac{795\,959 \times 8}{14 \times 12} = 37\,906;$$

$$h\,z = 3.93.$$

*Example of Slab:*

$A$ (assumed) $= 0.5$; $p$, $u$ and $z$, same as above;

$M = 88\,440$;

$W = 7\,370$.

Professor Hatt's constants:

$E_c = 4\,130\,000$; $n = 16$; $o = 250$.

Then $z = 0.345$, and $c = 2\,000$.

*Beam:* $M = 775\,226$;

$W = 36\,915$.

*Slab:* $M = 86\,136$;

$W = 7\,178$.

*3.*—Edwin Thacher, M. Am. Soc. C. E., proposes the following formula.* In the form here given, it is modified to apply to any width, $b$, of beam instead of a beam 1 in. wide.

Let $f$ = the stress per square inch on the steel, the gross area = the ultimate strength per square inch of the test piece + 10%;

* *Transactions*, Assoc. of C. E. of Cornell Univ., for 1902.

$E_c$ = the modulus under a pressure of from 1 000 to 2 000 lb. per sq. in.; Mr. Wason.

$$y = \frac{d}{\left(\frac{c}{f} \times \frac{E_s}{E_c} + l\right)};$$

$$x = d - y;$$

$$A = \frac{d\,b}{2\left[\frac{f}{c} + \left(\frac{f}{c}\right)^2 \times \frac{E_c}{E_s}\right]};$$

$$M = \frac{f}{3}\left[\frac{E_c}{E_s}\frac{x^3}{y}\,b + 3\,A\,y\right];$$

$$W = \frac{24\,f}{91}\left[\frac{E_c}{E_s} \times \frac{x^3}{y}\,b + 3\,A\,y\right],$$

for a load uniformly distributed.

To design a beam, assume values of $f$, $E_s$, $E_c$, $c$, $b$ and $d$. For other systems of loading or of support, the coefficients in the equations for $M$ and $W$, outside the bracket, would change.

*Example of Beam:*

$$y = \frac{12}{\frac{2\,000}{50\,000} \times \frac{30\,000\,000}{3\,000\,000} + 1} = 8.57;$$

$$x = 3.43.$$

$$A = \frac{12 \times 12}{2\left[\frac{50\,000}{2\,000} \times \frac{(50\,000)^2}{2\,000} \times \frac{3\,000\,000}{30\,000\,000}\right]} = 0.82;$$

$$M = \frac{50\,000}{3} \times \left[\frac{3\,000\,000}{30\,000\,000} \times \frac{3.43^3}{8.57} \times 12 + 3 \times 0.82 \times 8.57\right]$$

$$= 445\,499;$$

$$W = 21\,214.$$

*Example of Slab:*

$y = 2.86$; $x = 1.14$; $A = 0.274$; $M = 49\,500$; $W = 4\,125$.

Mr. Thacher's units:

Factor of safety, $3\frac{1}{2}$.

$$E_c = 1\,220\,000;\ c = 2\,050;\ f = 64\,000 + 10\%;$$

*Beam:*

$$A = \frac{b\,d}{165} = \frac{12 \times 12}{165} = 0.873;$$

$$M = 30.62\,d^2 \times 12 \times 12 = 634\,936;$$

$$W = 30\,235;$$

$$y = \frac{12}{\frac{2\,050}{70\,400} \times \frac{30\,000\,000}{1\,220\,000} + 1} = 7.01;$$

$$x = 4.99;$$

*Slab:* $A = 0.291$; $y = 2.33$; $x = 1.67$; $M = 70\,548$; $W = 5\,879$.

Mr. Wason.

*4.*—William H. Burr, M. Am. Soc. C. E., gives these formulas* for rectangular beams for the special case where the tension in the concrete is neglected and the steel is on the tension side only:

$$x = -\frac{E_s A}{E_c b} \pm \sqrt{\left(\frac{E_s A}{E_c b}\right)^2 + 2\,\frac{E_s A}{E_c b}\,d} = \frac{E_s}{E_c} \times \frac{d - x}{x}\,c = 34\,920;$$

$$M = c\left[\frac{b\,x^2}{3} + \frac{E_s}{E_c} \times \frac{A}{x}\,(d - x)^2\right].$$

*Example of Beam:*

$A$ (assumed) $= 1.5$;

$$x = -\frac{30\,000\,000 \times 1.5}{3\,000\,000 \times 12} \pm \sqrt{1.25^2 + 2 \times 1.25 \times 12} = 4.37;$$

$$M = 2\,000\left[\frac{12 \times 4.37^2}{3} + \frac{30\,000\,000 \times 1.5}{3\,000\,000 \times 4.37}\,(12 - 4.37)^2\right] = 552\,180;$$

$W = 26\,294.$

*Example of Slab:*

$A$ (assumed) $= 0.5$;

$$x = -0.417 \pm \sqrt{0.417^2 + 2 \times 0.417 \times 4} = 1.45;$$

$M = 61\,640$;

$W = 5\,137$.

Professor Burr's units:

$$c = 3\,100.$$

*Beam:* $x = 4.38$; $M = 855\,879$; $W = 40\,756$.

*Slab:* $x = 1.45$; $M = 95\,480$; $W = 7\,957$.

*5.*—A. L. Johnson, M. Am. Soc. C. E., proposes the following:

$f$ = elastic limit of the steel;

$$y = \frac{2\,f\,E_c}{3\,c\,E_s}\,x; \quad x + y = d;$$

$$A = \frac{75\,c\,b\,x}{120\,f};$$

$$M = f\,A\left(y + \frac{2\,x}{3}\right).$$

*Example of Beam:*

$$y = \frac{2 \times 50\,000 \times 3\,000\,000}{3 \times 2\,000 \times 30\,000\,000}\,x = 1.67\,x;$$

$x + y = 12$;

$x = 4.50$;

$y = 7.50$;

$$A = \frac{75 \times 2\,000 \times 12 \times 4.5}{120 \times 50\,000} = 1.35;$$

* "The Elasticity and Resistance of the Materials of Engineering," 1903 edition.

Mr. Wason.

$$M = 50\,000 \times 1.35 \left(7.50 + \frac{2 \times 4.5}{3}\right) = 708\,750;$$

$$W = 33\,750.$$

*Example of Slab:*

$$y = 2.5; \quad x = 1.5; \quad A = 0.45;$$

$$M = 78\,750; \quad W = 6\,563.$$

Mr. Johnson's units:

$$E_s = 29\,000\,000; \quad y = 1.72\,x; \quad x = 4.41; \quad A = 0.0195\,b\,x = 1.32;$$

$$M = 2\,750\,b\,x^2 = 641\,850; \quad W = 30\,564.$$

*Slab:* $x = 1.47$; $A = 0.34$; $M = 71\,280$; $W = 5\,940$.

6.—J. Kahn, Assoc. M. Am. Soc., C. E., uses a compressive area different from that used by any other writer. See Fig. 14.

$f =$ the ultimate tensile stress in the steel;

$$y = \frac{15\,A + b\,d^2}{30\,A + 2\,b\,d};$$

$$M = f\,A\left(\frac{5}{8}\,x + y\right);$$

$b$ should never be less than $\frac{A\,f}{1\,800\,x}$.

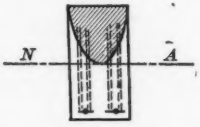



FIG. 14.

*Example of Beam:*

$$y = \frac{15 \times 1.5 + 12 \times 12^2}{30 \times 1.5 + 2 \times 12 \times 12} = 5.26;$$

$$A \text{ (assumed)} = 1.5;$$

$$M = 50\,000 \times 1.5\left(\frac{5}{8} \times 6.74 + 5.26\right) = 710\,250;$$

$$W = 33\,821.$$

*Example of Slab:*

$A$ (assumed) $= 0.5$; $y = 1.80$; $M = 79\,375$; $W = 6\,614$.

Mr. Kahn's units:

$$E_c = 2\,000\,000; \quad c = 3\,000; \quad f = 64\,000;$$

$$A \text{ (assumed)} = 1.5; \quad y = 5.26;$$

$$M = 64\,000 \times 1.5\left(\frac{5}{8} \times 6.74 + 5.26\right) = 909\,120;$$

$$W = 43\,291.$$

*Slab:* $y = 1.80$; $M = 101\,600$; $W = 8\,467$.

7.—A. N. Talbot, M. Am. Soc. C. E., proposes the following,* which is the special case for the ultimate deformation of concrete:

Let $p = \frac{A}{b\,d} =$ ratio of area of metal reinforcement to area of concrete above center of reinforcement;

* *Engineering Record*, August 13th, 1904; and *Journal* of Western Society of Engineers, August, 1904.

Mr. Wason.

$$z = \sqrt{\frac{2\,p\,n}{1-\frac{1}{3}} + \frac{p^2\,n^2}{(1-\frac{1}{3})^2}} - \frac{p\,n}{1-\frac{1}{3}};$$

$$V = \frac{3}{8}\,z\,d;$$

$$M = A\,f(d - V).$$

The solution of the values of $z$ and $V$ for smaller stresses than the ultimate is somewhat complicated. However, using the values of $z$ obtained by tests of 1:3:6 concrete beams, the formula becomes:

$$M = A\,f\,(0.906 - 6.5\,p)\,d.$$

This is a simple and convenient form to use.

*Example of Beam:*

$A$ (assumed) $= 1.5$;

$$p = \frac{1.5}{12 \times 12} = 0.01;$$

$$n = \frac{30\,000\,000}{3\,000\,000} = 10;$$

$$z = \sqrt{\frac{2 \times 0.01 \times 10}{\frac{2}{3}} + \frac{0.01^2 \times 10^2}{\frac{2}{3}}} - \frac{0.01 \times 10}{\frac{2}{3}} = 0.418;$$

$$V = \frac{3}{8} \times 0.418 \times 12 = 1.88;$$

$$M = 1.5 \times 50\,000 \times (12 - 1.88) = 759\,000;$$

$$W = 36\,143.$$

*Example of Slab:*

$$V = 0.63;$$
$$M = 84\,325;$$
$$W = 7\,027.$$

Professor Talbot's units:

$E_c$ = initial modulus average, 2 000 000; $n = 15$; $z = 0.482$; $V = 2.17$; $M = 1.5 \times 50\,000 \times 9.83 = 737\,250$; $W = 35\,107$.

*Slab:* $V = 0.72$; $M = 82\,000$; $W = 6\,833$.

*8.*—John S. Sewell, M. Am. Soc. C. E.

$$x + y = d;$$

$$y = \frac{f_1\,E_c}{c_1\,E_s}\,x;$$

$$y = \frac{f\,E_c}{0.8\,c\,E_s}\,x;$$

$$u = 0.64 + y.$$

Let $c_1 = 0.8\,c$;

$x - V = 0.64\,x$;

area under curve $= 0.57\,c_1\,x = 0.456\,c\,x$;

$0.465\,b\,c\,x = A\,f$;

$$M = 0.456 \times 0.64\,b\,c\,x^2 + A\,f\,y = 0.292\,b\,c\,x^2 + A\,f\,y.$$

Mr. Wason.

*Example of Beam:*

$$y = \frac{50\,000 \times 3\,000\,000}{0.8 \times 2\,000 \times 30\,000\,000}\, x = 3.125\, x;$$

$$x = 2.91; \quad y = 9.09; \quad u = 10.95;$$

$$A = \frac{0.456 \times 12 \times 2\,000 \times 2.91}{50\,000} = 0.637;$$

$$M = 0.292 \times 12 \times 2\,000 \times 2.91^2 + 0.637 \times 50\,0000 \times 9.09 = 348\,860;$$

$$W = 16\,612.$$

*Example of Slab:*

$$x = 0.97; \quad y = 3.03; \quad A = 0.212; \quad u = 3.65;$$

$$M = 0.292 \times 12 \times 2\,000 \times 0.97^2 + 0.212 \times 50\,000 \times 3.03 = 38\,706;$$

$$W = 3\,225.$$

Captain Sewell's units:

$$f = 45\,000; \quad c = 2\,500; \quad \frac{E_c}{E_s} = \frac{1}{15}.$$

*Beam:*

$$y = \frac{45\,000 \times 1}{0.8 \times 2\,500 \times 15}\, x = 1.5\, x; \quad x = 4.8; \quad y = 7.2; \quad u = 10.27;$$

$$A = \frac{0.456 \times 12 \times 2\,500 \times 4.8}{45\,000} = 1.46;$$

$$M = 0.292 \times 12 \times 2\,500 \times 4.8^2 + 1.46 \times 45\,000 \times 7.2 = 674\,870;$$

$$W = 32\,137.$$

*Slab:*

$$x = 1.6; \quad y = 2.4; \quad A = 0.486; \quad u = 3.42;$$

$$M = 0.292 \times 12 \times 2\,500 \times 1.6^2 + 0.486 \times 45\,000 \times 2.4 = 74\,914;$$

$$W = 6\,243.$$

*9.*—Mr. F. D. Warren has written a handbook * on reinforced concrete, in which there are a great many tables. In order to determine their value, the formulas based on the method of the late J. B. Johnson, M. Am. Soc. C. E., published in *Engineering News* in 1895, is submitted for review. An area of concrete equal to ten times the area of the steel is put in the same plane. The moment of inertia of this section is found, and the location of the neutral axis.

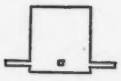


FIG. 15.

$$\frac{E_s}{E_c} = 10;$$

$M_o$ = working moment, factor of safety, $3\frac{1}{2}$;

$$\frac{M_o}{500} = \frac{1\, b\, d^3}{4\, d}$$

Preliminary step to find stress in compression in concrete; with factor of safety of 3.5 and $c = 3\,000$.

* "A Handbook on Reinforced Concrete," pp. 78-81.

Mr. Wason.

$$\frac{M_o}{f_1} = \frac{A\,h^2}{h}$$

{ Preliminary step to find area of steel; neutral axis assumed to be from 1.5 to 2.0 in. below the center of gravity of the section.

Transpose this area of steel into an area of concrete, and solve for the moment of inertia and the position of the neutral axis, neglecting the area of the concrete below the plane of the steel. If the neutral axis differs materially from 1.5 to 2.0 below the center of gravity, use this value to determine $h$ in the formula, $\frac{M_o}{f_1} = A\,h$, and with the new value again solve for $A$. Then check the fiber stress of the concrete in compression.

*Example of Beam:*

$$\frac{M_o}{333} = \frac{1\,b\,d^3}{4\,d}, \text{ when } c = 2\,000;$$

$$M_o = 83.33\,b\,d^2 = 83.33 \times 12 \times 12^2 = 144\,000, \text{ working load;}$$

$$M = 144\,000 \times 3.5 = 504\,000, \text{ ultimate load;}$$

$$\frac{M}{f} = \frac{A\,y^2}{y};$$

$y$ (assumed) $= 4.5$;

$$A = \frac{M}{f\,y} = \frac{504\,000}{50\,000 \times 4.5} = 2.24.$$

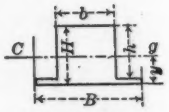


FIG. 16.

Assume 1-in. bars.

$$y = [BH - h(B-b)] = \frac{1}{2}\,B\,H^2 - h\,(B-b)\,(H - \frac{h}{2});$$

$$y = [34.4 \times 12.5 - 11.5\,(34.4 - 12)]$$

$$= 0.5 \times 34.4 \times 12.5^2 - 11.5\,(34.4 - 12)\,(12.5 - \frac{11.5}{2});$$

$$y = \frac{748.7}{172.4} = 4.34;$$

$x = 8.16$, or 2.16 below the central axis;

$$I = \frac{12 \times 12^3}{12} + 12 \times 12 \times 2.16^2 = 2\,400;$$

$$\frac{I}{x} = \frac{2\,400}{8.16} = 294;$$

$$c = \frac{504\,000}{294} = 1\,714;$$

$$A = \frac{M}{f\,y} = \frac{504\,000}{50\,000 \times 4.34} = 2.32.$$

*Example of Slab:*

$$M = 83.33 \times 3.5 \times 12 \times 4^2 = 56\,000;$$

Mr. Wason.

$$A = \frac{56\,000}{50\,000 \times 1.5} = 0.75;$$

$y$ (assumed) $= 1.5$.

Assume $\frac{1}{2}$-in. bars.

$$y = 19.5 \times 4.25 - 3.75\,(19.5 - 12)$$

$$= 0.5 \times 19.5 \times 4.25^2 - 3.75\,(19.5 - 12)\left(4.25 - \frac{3.75}{2}\right);$$

$$y = \frac{109.7}{54.88} = 2.00;$$

$x = 2.25$, or 0.25 below the central axis:

$$I = \frac{12 \times 4^3}{12} + 12 \times 4 \times 0.25^2 = 68.0;$$

$$\frac{I}{x} = 30.7;$$

$$A = \frac{56\,000}{50\,000 \times 2.0} = 0.56.$$

F. D. Warren's constants:

*Beam:* $c = 3\,000$; $f = 53\,000$; $f_1 = 15\,000$.

Factor of safety $= 3.5$.

$M_o = 125\,b\,d^2$;

$M = 125\,b\,d^2 \times 3.5 = 125 \times 12^2 \times 12 \times 3.5 = 756\,000$;

$A = \frac{M}{f\,y} = \frac{756\,000}{53\,000 \times 4} = 3.57$; $y$ (assumed) $= 4$; 1-in. bars assumed.

$$y = 47.7 \times 12.5 - 11.5\,(47.7 - 12)$$

$$= 0.5 \times 47.7 \times 12.5^2 - 11.5\,(47.7 - 12)\left(12.5 - \frac{11.5}{2}\right);$$

$$y = \frac{955.3}{185.7} = 5.14;$$

$x = 7.36$, or 1.36 below the central axis;

$$I = \frac{12 \times 12^3}{12} \div 12 \times 12 \times 1.36^2 = 1\,994.6;$$

$$\frac{I}{x} = 271;$$

$$c = \frac{756\,000}{271} = 2\,790;$$

$$A = \frac{756\,000}{53\,000 \times 5.14} = 2.78.$$

*Slab:*

$M = 125 \times 12 \times 4^2 \times 3.5 = 84\,000$;

$A = \frac{84\,000}{53\,000 \times 1.75} = 0.906$;

$y$ (assumed) $= 1.75$;

Mr. Wason.

$$y = [21 \times 4.25 - 3.75\,(21 - 12)]$$

$$= 0.5 \times 21 \times 4.25^2 - 3.75\,(21 - 12)\left(4.25 - \frac{3.75}{2}\right);$$

$$y = \frac{109.6}{55.5} = 1.98;$$

$x = 2.27$, or 0.27 below the central axis;

$$A = \frac{84\,000}{53\,000 \times 19.8} = 0.80$$

An examination of the results in Table 2 will show that in three of the nine there is a fairly close agreement with each other, whether with the use of the same constants for all, or the constants recommended by each author, although the assumptions of each are quite different. The three which agree fairly well are: Wason, Hatt, and Talbot. These three, then, would appear to be the most general in character, and the writer's method gives the safest result with the same constants. Professor Talbot's analysis appears to be the most rational solution of the problem, from a profoundly scientific standpoint.

Without doubt, the stress diagram of the concrete in compression is a curve somewhat resembling a parabola. No allowance for tension of concrete should be made. There seems to be, among many writers, a lack of appreciation of the fact that results obtained by solving for the ultimate strength of a reinforced concrete beam, then dividing by a given factor of safety, or using the corresponding working stresses to solve for the working strength of a beam, do not give the same results or results which can be compared. To illustrate: Take the beam previously considered, and the ultimate strength of the concrete as the force, instead of the area of the steel, with the parabolic treatment of the compression, and the neutral axis at one-half the depth to the center of the reinforcement.

$$\text{Then, arm of ultimate moment} = \frac{5}{8} \times \frac{1}{2}\,d + \frac{1}{2}\,d = 0.8125\,d;$$

$$\text{compressive force of concrete} = \frac{5}{8}\,c \times \frac{1}{2}\,d\,b = 0.3125\,c\,d\,b;$$

$$M = 0.254\,c\,d^2\,b = 0.254 \times 2\,000 \times 12 \times 12^2 = 877\,824;$$

$$\frac{1}{4}\,M = \text{working moment};$$

$$M_o = 219\,456.$$

If we use an outside fiber stress of one-quarter of the ultimate, namely, $c^1 = 500$, and solve for the working moment of resistance with the triangular, straight-line treatment of compression (see Fig. 17), then,

$$\text{Arm of working moment} = \frac{2}{3} \times \frac{1}{2}\,d + \frac{1}{2}\,d = 0.833\,d;$$

Mr. Wason.

compressive force of concrete $= \frac{1}{2}\ c^1 \times \frac{1}{2}\ b\ d = 0.25\ c^1\ b\ d$;

$M_0 = 0.208\ c^1\ b\ d^2 = 180\,000.$

The correct method is to solve for the working strength. Assuming a working compressive stress of one-fourth the ultimate, the difference between the straight line and the parabola is negligible, and the triangular area can be used, as it is simpler. The variation in the quality of the best concrete will more than offset the refinement of retaining the curve. If the triangular area is used for ultimate compression, the result will be too large, in the ratio of $\frac{1}{2}$ to $\frac{5}{16}$, or $37\frac{1}{2}$ per cent. The modulus of elasticity is used only in finding the position of the neutral axis, in order to find the center of gravity of the compressive force. The position of the neutral axis is of very little value.

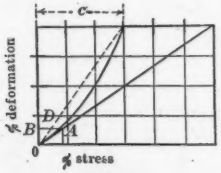



FIG. 17.



FIG. 18.

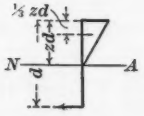



FIG. 19.

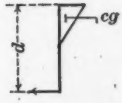



FIG. 20.

To illustrate, take two extreme cases: First, $E_c = 4\,500\,000$ and $\frac{1}{2}\%$ of steel; secondly, $E_c = 1\,250\,000$ and $2\%$ of steel. Then, by Talbot's formula: First case, $z = 0.266$; second case, $z = 0.616$.

Arm of moment $= d - \frac{1}{3}\ z\ d$

| | | |
|---|---|---|
| First case | " " " | $= 0.925\ d$ |
| Second case | " " " | $= 0.795\ d$ |
| Mean..... | | $= 0.86\ d$ |

The difference is $0.13\ d$ or 14 per cent. If a factor of safety of 4 is used on the crushing strength of concrete, then the 14% of ultimate strength is only $3\frac{1}{2}\%$ of the working strength. Greater differences are frequently found among several test specimens made from the same batch. As the case cited covers a wide range, from a rich mixture at an age of several months, with insufficient reinforcement, to a lean mixture at the age of one month, with an excess of metal, with an error negligible in common practice, it is evident that no change is necessary in the formula for any ordinary cases of construction, because they always fall within these limits. This adds greatly to the simplicity of making designs, and to universality in the use of tables.

Mr. Wason.

TABLE 2.—SUMMARY OF RESULTS USING THE SAME CONSTANTS:

FOR BEAMS.

| Author. | Ultimate bending moment, in pounds. | Breaking load, in pounds. | Area of steel, in square inches. | Stress in steel, in pounds per square inch. | Distance, top to neutral axis, in inches. | Arm of moment of resistance, in inches. | Arm, as percentage of $d$. |
|---|---|---|---|---|---|---|---|
| Wason..... | 750 000 | 35 714 | 1.5 | 50 000 | 6.00 | 10.00 | 0.833 |
| Hatt..... | 795 939 | 37 906 | 1.5 | 50 000 | 3.93 | 10.53 | 2.877 |
| Thacher.... | 445 499 | 21 214 | 0.82 | 50 000 | 3.43 | 10.86 | 0.905 |
| Burr..... | 552 180 | 26 294 | 1.50 | 34 920 | 4.37 | 10.54 | 0.878 |
| Johnson.... | 708 750 | 33 750 | 1.35 | 50 000 | 4.50 | 10.32 | 0.86 |
| Kahn..... | 710 250 | 33 821 | 1.50 | 50 000 | 6.74 | 9.47 | 0.789 |
| Talbot..... | 759 000 | 36 143 | 1.50 | 50 000 | 5.02 | 10.12 | 0.843 |
| Sewell..... | 348 860 | 16 612 | 0.64 | 50 000 | 2.91 | 10.95 | 0.913 |
| Warren..... | 504 000 | 24 000 | 2.24 | 50 000 | 8.16 | 9.28 | 0.773 |

FOR SLABS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wason..... | 83 333 | 6 944 | 0.5 | 50 000 | 2.00 | 3.33 | 0.833 |
| Hatt..... | 88 440 | 7 370 | 0.5 | 50 000 | 1.31 | 3.51 | 0.877 |
| Thacher.... | 49 500 | 4 125 | 0.28 | 50 000 | 1.14 | 3.62 | 0 905 |
| Burr..... | 61 640 | 5 137 | 0.5 | 34 920 | 1.45 | 3.52 | 0.878 |
| Johnson.... | 78 750 | 6 563 | 0.45 | 50 000 | 1.50 | 3.44 | 0.86 |
| Kahn..... | 79 375 | 6 614 | 0.5 | 50 000 | 2.20 | 3.18 | 0.795 |
| Talbot..... | 84 325 | 7 027 | 0.5 | 50 000 | 1.67 | 3.37 | 0.842 |
| Sewell..... | 38 706 | 3 225 | 0.21 | 50 000 | 0.97 | 3.65 | 0.913 |
| Warren..... | 56 000 | 4 667 | 0.57 | 50 000 | 2.25 | 3.25 | 0.812 |

SUMMARY OF RESULTS USING EACH AUTHOR'S CONSTANTS:

FOR BEAMS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wason..... | 750 000 | 35 714 | 1.5 | 50 000 | 6.00 | 10.00 | 0.833 |
| Hatt..... | 775 226 | 36 915 | 1.5 | 50 000 | 4.66 | 10.25 | 0.854 |
| Thacher.... | 634 936 | 30 235 | 0.87 | 70 400 | 4.99 | 10.33 | 0.861 |
| Burr..... | 855 879 | 40 756 | 1.5 | 53 940 | 4.38 | 10.54 | 0.878 |
| Johnson.... | 641 850 | 30 564 | 1.32 | 50 000 | 4.41 | 10.35 | 0.863 |
| Kahn..... | 909 120 | 43 291 | 1.5 | 64 000 | 6.74 | 9.47 | 0.789 |
| Talbot..... | 737 250 | 35 107 | 1.5 | 50 000 | 5.78 | 9.83 | 0.819 |
| Sewell..... | 674 870 | 32 137 | 1.46 | 45 000 | 4.8 | 10.27 | 0.856 |
| Warren..... | 756 000 | 36 000 | 2.78 | 53 000 | 7.36 | 9.55 | 0.792 |

FOR SLABS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wason..... | 83 333 | 6 944 | 0.5 | 50 000 | 2.00 | 3.33 | 0.833 |
| Hatt..... | 86 136 | 7 178 | 0.5 | 50 000 | 1.55 | 3.42 | 0.855 |
| Thacher.... | 70 548 | 5 875 | 0.29 | 70 400 | 1.67 | 3.44 | 0.86 |
| Burr..... | 81 933 | 6 828 | 0.5 | 53 940 | 2.15 | 3.28 | 0.82 |
| Johnson.... | 71 280 | 5 940 | 0.34 | 50 000 | 1.47 | 3.45 | 0.862 |
| Kahn..... | 101 600 | 8 467 | 0.5 | 64 000 | 2.20 | 3.18 | 0.795 |
| Talbot..... | 82 000 | 6 833 | 0.5 | 50 000 | 1.93 | 3.28 | 0.82 |
| Sewell..... | 74 914 | 6 243 | 0.49 | 45 000 | 1.6 | 3.42 | 0.855 |
| Warren..... | 84 000 | 7 000 | 0.80 | 53 000 | 2.27 | 3.24 | 0.810 |

Mr. Wason.

In a large number of tests examined, the neutral axis for one-quarter of the ultimate load has been found to be not far from one-half the depth from the top of the beam to the center of reinforcement. It is sometimes above and sometimes below. To assume it half way, agrees very closely, therefore, with the observed facts. With this position and a straight-line distribution within the working stress, the center of gravity of the compressive stresses is two-thirds of the distance up from the neutral axis to the top of the beam. Therefore, the arm of the moment of resistance is $\frac{5}{6} d = 0.833\ d$.

The method of designing beams with a T-section need not add complications. The foregoing formula can be applied without difficulty. The same value of $u$ can be used as for a rectangular beam, inasmuch as the center of gravity of the compressive forces for the T-section, usually, will nearly coincide with that for the rectangular one, and if it does not, $u$ will be less than its true value, therefore the beam will be somewhat heavier than is necessary. If the depth and size of the steel are fixed, it is then merely necessary to find a sufficient area of concrete to balance this; or take the maximum allowable width of flange, which usually may be taken as four times the width of the web, and from the other known dimensions of the section, the area in compression may be obtained. Knowing the ratio of the allowable working stresses in the concrete and the steel, the area of the steel is fixed. One advantage of this formula is that the area of the concrete above the neutral axis multiplied by its average stress may be substituted for the area of the steel.

In the writer's practice, he has never known a case where a floor was composed of concrete leaner than 1:3:6, or richer than 1:2:4, and as a designer will generally use one mixture at all times, there is no complication by a large number of ratios of areas of steel to concrete, as the percentage is a fixed amount determined entirely by the working stress of each material. In using such a formula, it is as easy to check existing work designed by others as to design new work independently by it.

In using the method proposed by Professor Hatt, there are too many variables depending upon one another. The position of the neutral axis varies with the percentage of the area of reinforcement to that of the concrete; the ratio of moduli of elasticity of the two materials, which in turn varies with the mixtures, age, and character of the cement, sand and stone; and the stress-strain curve differs for each case. Moreover, the position of the neutral axis is of little consequence. Its position is not accurately known at the ultimate strength of the beam, therefore the value of $c$, corresponding with a given $f$, is only approximate. The location of the first crack is also too variable to be a safe guide to the proper working load. He places the steel too near the bottom of the beam.

Mr. Wason. The method proposed by Mr. Thacher appears to be in error in finding the value of $A$, which is carried into the solution of the moment of resistance. The writer has never found the percentage of steel per inch of width of beam useful in designing structures.

Professor Burr places the ultimate strength of the concrete too high, and does not get full efficiency from the steel.

Mr. A. L. Johnson stakes his reputation and his design on the fact that reinforced concrete stretches more than plain concrete; to quote his own words:*

"As stated in the introduction, this effect of the embedded metal upon the extensibility of the concrete is the quality upon which the whole art of steel-concrete construction rests. Fortunately, it is a quality as to the existence of which there can be no doubt. The art had been a success for many years before science stepped in to tell us why."

Mr. Kahn's method the writer has been unable to check by any of the ordinary principles of design, and he sees no logical reason for the area used in compression.

Professor Talbot's formula is the most rational of any yet proposed, covering every point, and it can be readily applied to any degree of loading. It is in the form proposed for the universal formula.

Captain Sewell bases his determination for the position of the neutral axis upon the ratio of the moduli of elasticity and the working stress of the two materials. As these do not vary proportionally, results based upon this method are inaccurate. Moreover, with concrete wherein the modulus and stress are not proportional, the assumption that a plane before bending is a plane after bending is open to doubt. He states that the values of $c$ and $E_c$ must always be those that correspond to each other. The value of $c$ differs somewhat with different brands of cement, and, as the designer does not know what brand will be used in his work, the correct ratio of $c$ to $E_c$ may not be used, and a safe value for all brands may not be economical. The writer's study of recent tests at the Watertown Arsenal led chiefly to the conclusion that it is best not to use a certain brand which was largely used in making these tests. The ultimate strength of several brands varied widely, yet the modulus at the same stress, approaching the ultimate load, varied but little. This is somewhat similar to the variation in the elastic limit and ultimate strength of steel with a change in the percentage of carbon, while the modulus of elasticity remains constant. This is a serious defect in the formulas involving ratios of these stresses.

Mr. Warren's method is a series of approximations, and the result is the same. Moreover, using his method involves a longer task

*Catalogue of St. Louis Expanded Metal Fireproofing Company, 1903, p. 53.

than any of the others. The result shows an extravagant use of steel and a lack of efficiency in the concrete. The stress in this material is not as great as his formula would indicate. A thickness of 1 in. of concrete below the steel is not enough when the size of the bar exceeds $\frac{3}{4}$ in. square. Mr. Wason.

Some engineers solve for the working stress of the beam, and use the parabolic curve for the compressive stresses. This is inaccurate, inasmuch as, within the working stresses, the stress is almost exactly proportional to the strain, so that a plot is either a straight line or its difference from a straight line is negligible. With this method of design, the outside fiber stress in compression is actually about $1\frac{1}{2}$ times as great as it is assumed, as shown below.

For a parabolic curve: $c = 500$; $p = 0.01$; $n = 10$; $x = 0.42$.

$$\frac{M}{b\,d^2} = \frac{2}{3}\,c\,x\left(1 - \frac{3}{8}\,x\right) = \frac{2}{3} \times 500 \times 0.42\left(1 - \frac{3}{8} \times 0.42\right)$$
$$= 140\,x \times 0.843 = 118.$$

For a straight line: $c = 750$; $p = 0.01$; $n = 10$; $x = 0.36$.

$$\frac{M}{b\,d^2} = \frac{c}{2}\,x \times \left(1 - \frac{x}{3}\right) = \frac{1}{2} \times 750 \times 0.36\left(1 - \frac{0.36}{3}\right)$$
$$= 135 \times 0.88 = 118.8.$$

$x$ is taken from diagrams, using $p$ as ordinates and $x$ as abscissas for given values of $n$, $x$ being deduced from the formula for a parabola:

$$x = -\frac{3}{2}\,n\,p + \sqrt{\left(\frac{3}{2}\,n\,p\right)^2 + 3\,n\,p};$$

and for a straight line:

$$x = -\,n\,p + \sqrt{(n\,p)^2 + 2\,n\,p}.$$

These plots were made by Professor Arthur W. French. It will be seen that the results are almost identical, although $c = 500$ in one case and 750 in the other.

Captain Sewell's taking 80% of the ultimate strength as a maximum stress on the concrete when the steel reaches its elastic limit is apparently based on Professor Hatt's tests at the first crack. The working stress obtained in concrete on this basis, using $2\frac{1}{2}$ as a factor of safety, or 32% of the ultimate strength, seems to be reasonable. The writer would recommend using the sum of the dead and live loads as the load on which the factor is based, except in the rare cases where the dead load is larger than the live load, when (live load + $\frac{4}{10}$ dead load) $\times$ $2\frac{1}{2}$ = the elastic limit of the steel, may be used. The limit of elastic deformation determined by Professor Bauschinger, which the writer has never seen questioned, was about seven-tenths of the ultimate resistance; therefore, approxi-

Mr. Wason. mately, the above factor of safety is based on the elastic limit of the concrete as well as of the steel.

In designing, it is assumed that there are no initial strains in the composite structure, but, nevertheless, they exist, as the shrinkage of the cement in setting produces an initial compression in the steel which the formula does not recognize, and this, if neglected, adds to the factor of safety. Inasmuch as the amount of stress cannot be accurately determined, this is the wiser course.

Captain Sewell states that beams designed by the right line are heavier than necessary, and that the parabola rather inclines to the opposite extreme. When solving for the working stresses, this is of less consequence. His value, $u = 0.85$, agrees quite closely with the mean of the two extreme cases previously solved by Professor Talbot's formula, and is sufficiently accurate to be generally used if the curved stress-strain principle be accepted as correct. The writer believes it is not correct when working stresses are considered.

The elaborate discussion as to the most economical design, considering the cost of the steel and the concrete, is very interesting and suggestive, but, inasmuch as the cost of the two materials is entirely independent of their ratio of stresses in practical application, the writer has found that it is sufficiently accurate and economical to design beams with the maximum allowable depth, in order to obtain the maximum of economy.

From every test which has come to the writer's attention, he is convinced that there is no economy in reinforcing the beam with steel against compression, and is glad to see this opinion confirmed. There is not as great economy in using it in compression as in tension, but the writer would go still further and say, from his present knowledge, that it is never advisable to use steel in compression in beams. The tests made for him at the Massachusetts Institute of Technology showed no value whatever in top reinforcement, and to rely on it would be dangerous.

There are other reasons to prevent a theoretically accurate design from being actually carried out on the work. As the ultimate strength and modulus of elasticity increase with age, while the steel does not, the design of the beam becomes unbalanced, thus changing the ratio of the moduli of the two materials, the position of the neutral axis, and, especially important, the ultimate compressive stress, thus changing the expected result from any design where these items are used as factors. Actual transverse tests, where the neutral axis has been located, show that the outside fibers sustain a greater stress than in columns uniformly compressed.

On work of any size, the concrete is mixed by machinery, while laboratory tests are almost invariably mixed by hand. Samples of hand-mixed concrete from actual work give better results than labo-

ratory specimens. In two sets of tests, reported at the Watertown Arsenal in 1897 and 1900, the difference in strength between hand-mixed and machine-mixed concrete, where both cases were exceptionally well done, was 11% in favor of the machine-mixed. In the other set, under commercial conditions, the difference was 25% in favor of the machine-mixed. There is quite a difference in the modulus of machine-mixed and hand-mixed concrete. Wet or plastic mixtures thoroughly, or lightly tamped affect the density and the bond with steel. Mr. Wason.

The bond or union between the steel and the concrete increases with age. The adhesion does not reach a very high value in one month, but increases steadily beyond this point for a number of months. Thus, a design based on adhesion which would not be safe at one month would be safe at a greater period. A mechanical bond is always to be preferred to simple adhesion, however. While the formulas given take no notice of this, the designer must, before completing his work.

Fortunately, all these variations are in the direction of safety, but when natural causes, of which the most elaborate formula can take no cognizance, produce such differences, why attempt great refinement, especially when the values of the several factors cannot be determined with absolute precision?

The discussion resolves itself into:

1. Should the ultimate or the working stresses be used;

2. What arm should be given to the internal moment of resistance, the formula to be used being in the form:

$$M = u\, d\, A\, f.$$

The arm proposed by the writer, $\frac{5}{6}\, d$, or 0.833 $d$, is 1.7% safer than that proposed by Captain Sewell, and he believes it is more nearly correct.

There are many rules in practice for the quantity of concrete necessary to embed the steel in the bottom of a beam. The practice followed by the writer, which has proved entirely satisfactory in twelve years of practice, is to use a quantity equal to twice the diameter of the bar below its center. In work of exceptional importance, or where there is unusual danger from exposure to fire, this may be increased to $2\frac{1}{2}$ times the diameter of the bar, and this will be found to be ample in the worst cases. The width of the beam should be at least equal to 3 times the diameter of the bar. If this is used as a minimum, there is danger in some cases of shear cracks. Adding an inch to the amount above given, or, at most, 4 times the section of the bar, will be found sufficient for beams reinforced with a single bar. Where more than one is used, allow a clear space between the bars equal to their diameter.

Mr. Wason.

A good deal has been said by various writers about the percentage of steel to use. The limiting factor is the area of the concrete. After once determining the working stress of this, the percentage of steel is fixed for any given stress, and this ratio is a constant.

Among the advantages of solving for the working stress, in addition to those previously advanced, is the fact that a great many tests of the crushing strength of concrete of different mixtures and brands of cement have been made when measurements have not been taken to determine its elastic quality. A general average of all these is easy to obtain, or an average omitting the exceptionally high ones, and this may be used as the ultimate strength. In obtaining results of this character, there is no danger of misinterpreting their meaning. The variations in the actual results from those theoretically expected are well within the limits of allowable error. The advantage in commercial practice of all work of different designers agreeing in their principle with one another is as important as in designs made for wood and steel.

In all the foregoing, nothing has been said about web stresses. When the writer began constructing this class of work, twelve years ago, he did not know enough to reinforce the beams against shear. There are a good many structures without any reinforcement which have proved entirely satisfactory in actual service. On account of this experience, he still continues to build many floors for light loads without any web reinforcement. There is one building, however, in which the floors are habitually heavily overloaded by the shock of falling weights. In this, some beams have been cracked, which would indicate there is not a very large factor of safety, and therefore reinforcing against web stresses is desirable. From the experience of actual structures without web reinforcement, and from laboratory tests, it is evident that the concrete will withstand a considerable part of the web stresses, enabling the beam to develop nearly the ultimate strength of its tension and compression members. The writer dissents, therefore, from Captain Sewell's opinion that concrete should no more be relied upon for connections than for resisting tensile flange stresses. Especially is this true when economy is considered.

When beams are to carry a quiet load, or one with but little vibration, the concrete can be allowed to resist shear to the amount of 80 lb. per sq. in. But when there is heavy vibration or sudden shocks, reinforce for the entire web stress. On account of the frequent lapse of time between filling a beam and spreading the panel or flange portion of the floor, it is advisable to use stirrups bent to extend at least 1 ft. each way from the beam into the panel to bond the two together. This is seldom done. It is most needed at the center of the span. Deformed bars are far superior to plain ones, and, now

that there is little difference in price between them, there is no excuse whatever for the use of plain bars. Mr. Wason.

In comparative tests, where some of the main bars were bent diagonally upward, reaching the top of the beam near the support, the greatest strength was obtained—25% greater than with the use of diagonal stirrups attached rigidly to the main bars. This latter method, however, is far superior to diagonal stirrups which are loose, as in tests of this kind, when the beam deflected, they dragged under the main bars, breaking away the concrete and causing failure at a lower load than a beam which had no web reinforcement whatever. Loose vertical stirrups gave better results than beams without any web members. It is harder work to embed diagonal web members properly, as shown on page 657,* than with vertical ones, or where some of the main bars are bent diagonally upward to the top of the beam. Therefore, to obtain as good results with the inclined stirrups requires more expense and smaller stone in the concrete than is required with other types.

This discussion, however, can be made entirely independent of that of flexure, and final judgment should be reserved until more experimental data have been obtained. Some of the colleges are conducting such experiments at the present time, the results of which it is expected will throw considerable light upon this subject. The writer, therefore, has merely stated his experience, which may help toward the ultimate solution.

E. P. GOODRICH, M. AM. SOC. C. E.—For several years the speaker has had in mind the use of a simple formula, such as the one suggested by Captain Sewell, to be used in the design of reinforced concrete beams. With this in view, the results of tests of several hundred beams have been carefully analyzed and plotted. After considerable work had been done, the speaker's attention was called to a paper by T. L. Condron, M. Am. Soc. C. E., entitled "A Study of Tests of Reinforced Concrete Beams," presented before the American Society for Testing Materials. In it Mr. Condron has analyzed eighty-three tests, and has proposed a formula of the form. Mr. Goodrich.

(Moment of forces) $\div$ (depth $\times$ area of beams) = (constant $\times$ percentage of steel) + (another constant).

The paper is most interesting and is worthy of close study.

Several engineers had been making use of simplified formulas before L. J. Johnson, M. Am. Soc. C. E., published, in *Engineering News*, his table of the values of $K$ (which corresponds with Captain Sewell's $h$). As far as the writer is aware, however, Professor Johnson was the first to put the theoretical side of the subject into such shape that a simple formula was available for practical use.

Because of the diversity of composition and age of the tested

*Proceedings*, Am. Soc. C. E., for December, 1905.

Mr. Goodrich.

beams, reports of which were available for examination by the speaker, it was difficult to determine the accuracy of Mr. Condron's deductions. The speaker, therefore, instituted the following test: Seven beams were built, with tension rods only, and all had the same area of steel and the same area of concrete above the reinforcement. The breadth and depth of the several beams were varied as far as possible. With these conditions, the breaking load should vary directly with the depth of the beam, according to Mr. Condron's equations. The beams broke with remarkable uniformity, all failing by crushing.

Fig. 21 shows the plotted results. The results also clearly show the possibility of using such a formula as that proposed by the author, at least when a single percentage of steel is used.

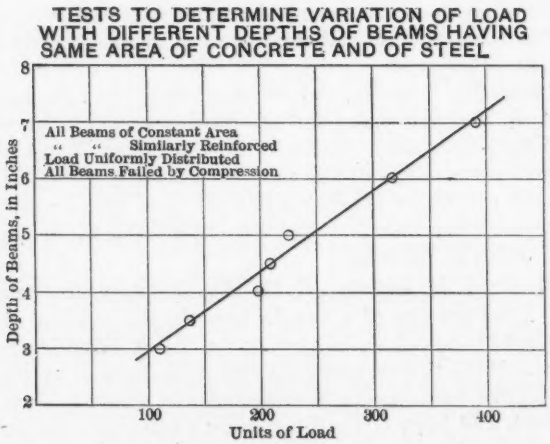



FIG. 21.

The analysis of the various test beams developed several different points, one of which was the fair constancy of a quantity corresponding with the $h$ of the author's formula. Even the several hundred examples, however, were found to be altogether too few, upon which to base perfect reliance, and the speaker has thus been forced to resort largely to theory in order to develop working rules for design; but these rules are well tinctured with the deductions from the experiments analyzed.

The author's work, in analyzing the Watertown compression tests to arrive at a proper assumption as to the stress-strain curve, is in direct line with what he states must be done as a solid basis upon which to construct working formulas. It is an indirect method, but, nevertheless, of great value.

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His objection, that the assumption of a right line as the stress-strain curve for concrete gives beams which are unnecessarily heavy, may be true from the point of view of theory only, and perhaps may be proved so in practice when only the best of workmanship is exacted. However, when consideration is given to the fact that probably a large majority of the reinforced concrete work going on at the present time is being done by inexperienced contractors, employing relatively low-grade labor, and under little or no supervision, the speaker believes that the Building Department of the City of New York, the Prussian Government, and the French Commission have taken a wise course in specifying the right-line assumption. In the example given by the author, he shows an increase of only $\frac{1}{2}$ in. for a beam which would have a depth of 8 in., according to his method of design. This is an addition of only $6\frac{1}{4}\%$, which is very small to cover even ordinary variations in workmanship, and is only $3\frac{3}{4}\%$ more than enough to cover the variation from the nominal weight of steel bars allowed in the rolling mills, according to standard steel specifications.

On the basis of concrete at 20 cents per cu. ft., steel at 3 cents per lb., and 1% of steel used as reinforcement, a variation in cost of only 3.6% is found between the right line and the author's assumptions. While bars usually run over weight, still there is a real chance of a possible deficiency, in the carrying power of a beam, of as much as $2\frac{1}{2}\%$, against which safe practice recommends a constant increased cost of only 3.6 per cent.

What the author says as to the proper definition of the modulus of elasticity of concrete is only too true. The speaker has been unable to find any data as to the modulus for concrete 14 days old, which is the age at which he determines all working values, and has been forced to assume one until such time as accurate tests can be secured. He has lately come to the conclusion that the usual ratios assumed for the moduli are too small.

Fig. 22 shows the curves representing the theoretical percentage of depth from the top of a beam to the neutral axis, for different percentages of steel and ratios of moduli, based on a right line for the stress-strain diagram. On it are also plotted the actual locations of the neutral axis determined by measurements on the beams tested by A. N. Talbot, M. Am. Soc. C. E., and reported to the Western Society of Engineers. It is seen that the curve coming nearest to the observed results would be for approximately 18, as a ratio of moduli.

Another illustration, tending to prove this conclusion, was of a test beam designed with stirrups of the special type adopted by the speaker. When only 14 days old it failed by compression under a center load of 16 000 lb. The effective beam area was 7 in. wide by

Mr. Goodrich. 10 in. deep, and the clear span was 100 in. On the assumption of a right line for the stress-strain diagram, and a ratio of 12 for the ratio of moduli, the extreme fiber stress at failure was 3 800 lb. With a ratio of 20, the fiber stress was 2 750. This means one or both of two things: the ratio of moduli assumed in the first case was altogether too small, or the type of stirrup had much to do with raising the extreme fiber stress. Probably both are true. These points, with many others, make the speaker feel that values for $r$ below 15 are really too small. This is most likely to be true with certain designs of web reinforcement which act to stiffen the beam.

The speaker agrees with the author when he says that the "most logical" method of design is to compute the load producing the

LOCATION OF NEUTRAL AXIS FOR TALBOT'S TESTS WITH REFERENCE TO THE THEORETICAL LOCATION FOR VARIOUS RATIOS OF THE MODULI OF ELASTICITY, USING A RIGHT LINE AS STRESS-STRAIN CURVE FOR CONCRETE

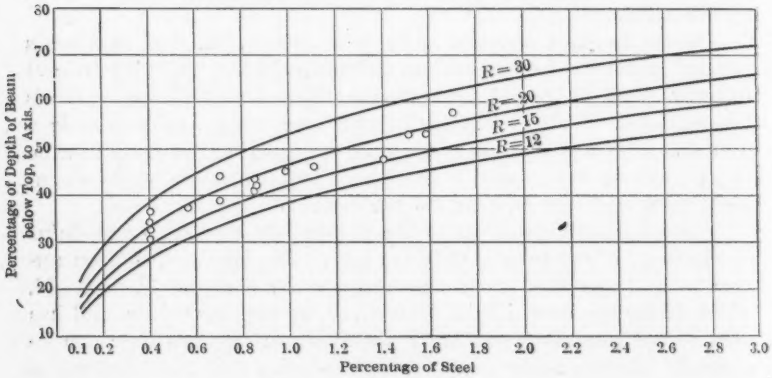



FIG. 22.

maximum stress "as the dead load, plus the product of the working live load by a factor of safety." That is the method adopted by the speaker for all his work.

It is interesting to note that, after all his work, the author finds that the average values of his quantity, $h$, vary only from 0.865 to 0.84, even with the widest range of theory as to the form of the curve in question. When he assumes a constant value of 0.85, he strikes almost exactly the one found for a steel stress of 40 000 lb. per sq. in. Both 40 000 and a value very close to 0.85 are the ones adopted by the speaker for all his ordinary work. In selecting 40 000, he agrees with the author as to adopting the elastic limit of the steel as one maximum stress.

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The speaker is also in substantial agreement with him as to the propriety of adopting, as a working value for the maximum stress for concrete, an amount reduced appreciably below the ultimate stress usually assumed for that material. The author, like most engineers, adopts 2 500 as the ultimate stress. He, however, reduces this amount by 20% and uses 2 000 as the maximum allowable stress on concrete. The speaker uses this same figure, but arrives at it by a different course of reasoning.

It is believed that almost all structural work, both of steel shapes and of reinforced concrete, is likely to receive its most severe test during erection, and that (in the case of concrete at least) it is most apt to occur about 14 days after the concrete has been placed. The centers are then removed or are being removed, and the structure is in such a condition that building materials and all sorts of things are likely to be piled about in the promiscuous way so well known to all engineers. Little thought is ever given to the actual weight involved, and overloading is known to be only too common.

The diagram found on page 257 of Taylor and Thompson's book, "Concrete, Plain and Reinforced," shows that the average ultimate compression stress in concrete 14 days old is about 85% of its ultimate stress at the age of one month. This tends to show that the reduction of 20% advocated by the author is a wise one, especially when conditions are considered which are apt to occur at an early age of the concrete.

For these reasons the speaker has prepared all his working formulas on a basis of 2 000, which is lower than has generally been used by most engineers, except through the devices of a relatively low safe working stress for concrete, or of a larger factor of safety for concrete than for steel.

The author suggests that experiment is best to determine "the maximum allowable percentages of steel for each grade of concrete." In this connection, the deductions made by Mr. Condron are of interest. He says:

"For plain steel bars of approximately 33 000 lb. per sq. in. elastic limit.....$P$ (is) not to exceed 1.5%," and for "corrugated or similar bars of approximately 55 000 lb. per sq. in. elastic limit.....1¼ per cent."

He does not give his reasons for the deductions, and the method of loading, and size and kind of reinforcement in the beam influence so largely the type of failure that some modification of such a general rule should be made, so as to meet varying conditions.

In this connection, the results of the tests made by H. A. Carson, M. Am. Soc. C. E., published in the report of the Boston Transit Commission for 1904, are of great interest. Fig. 23, at the left, shows the plotted results of tests of plain, square and other bars of

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low elastic limit. In all cases the failures are described as being due to "tension," except two with small percentages, in which one bar slipped. Fig. 23, at the right, shows results obtained with twisted and corrugated bars. In the tests marked with double circles, the beam failed by what the report designates as "shear," but which the speaker believes to be due primarily to a splitting of the concrete along the line of reinforcement because of the shape of the bar and its action when it begins to draw through the concrete as tension comes upon the reinforcing steel.

Since the beams reinforced with plain rods did not fail by shear or by slipping of the rods, even when the percentage of reinforcement was high, there is nothing to lead one to presuppose failure by shear in the cases of the beams with twisted and corrugated bars.

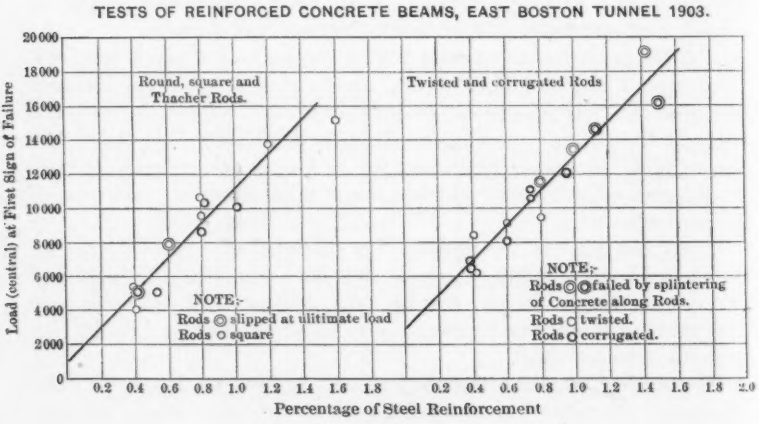



FIG. 23.

Fig. 1, Plate XXVII, is a reproduction of one of several photographs contained in the report, to which reference is specifically made as illustrating the type of failure in these cases. It may be contended that the bars were spaced too closely, so that not enough concrete surrounded the bars to bring them into proper action. This is doubtless true, but when sufficient concrete is available for this purpose, the design is a failure from the economical standpoint.

The tests made by Mr. Carson show that—for beams of the size involved, reinforced simply by tension bars, and broken by a center load—not more than 1% of any but plain steel bars should be used. It will be seen, later, that when stirrups are used, much larger percentages of steel can safely be utilized.

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The analytical work carried out by the author is extremely interesting in itself, but it is even more so when it is examined as to its agreement or disagreement with actual tests.

The speaker has investigated a great many theoretical designs based on almost every combination of conditions, and one set of results is shown in Fig. 24. The depths of beams of constant width, designed to support a given total load on a given span, with varying percentages of reinforcement, were computed. One curve was plotted showing the varying depth when only the steel was considered. Another curve was then found when the concrete alone

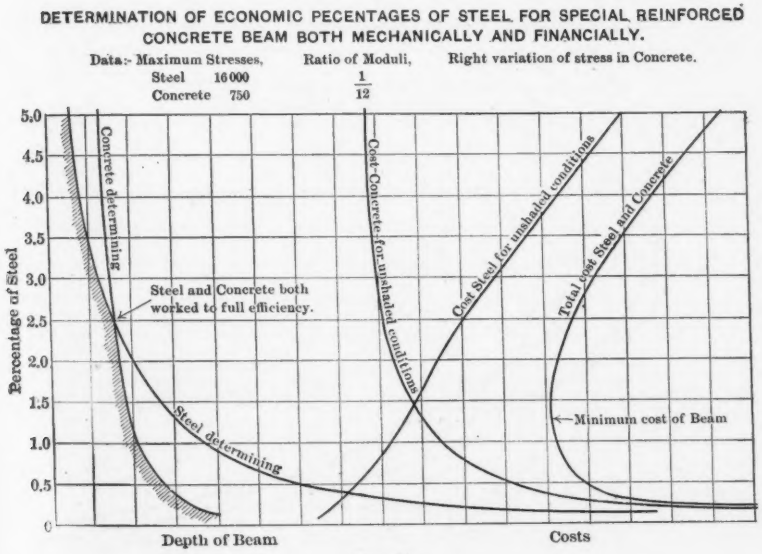



FIG. 24.

was kept in view. These two curves are at the left in Fig. 24, and where they cross is the only point at which both materials are worked to their full mechanical efficiency.

With a percentage of steel other than that found at the point of intersection of the curves, the depth is determined by one or other of the unshaded parts of the lines. The costs of both steel and concrete for beams of the depths determined by these unshaded lines were then computed, and are shown in the next two intersecting curves. The total cost is given by the line at the right, which shows a decided minimum. In this special case, however, the cost varies only slightly between 1 and 1½% of steel.

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With other assumptions as to the ratio of moduli of the maximum allowable stresses, and of the unit costs of the materials, the minimum occurs with other percentages of steel.

Some actual plotted costs are shown in Fig. 25, which includes Professor Talbot's tests with corrugated bars, and the Boston tests with square and with twisted bars. The minimum occurs between 1 and 1½% of reinforcement for the special prices assumed, *viz.*:

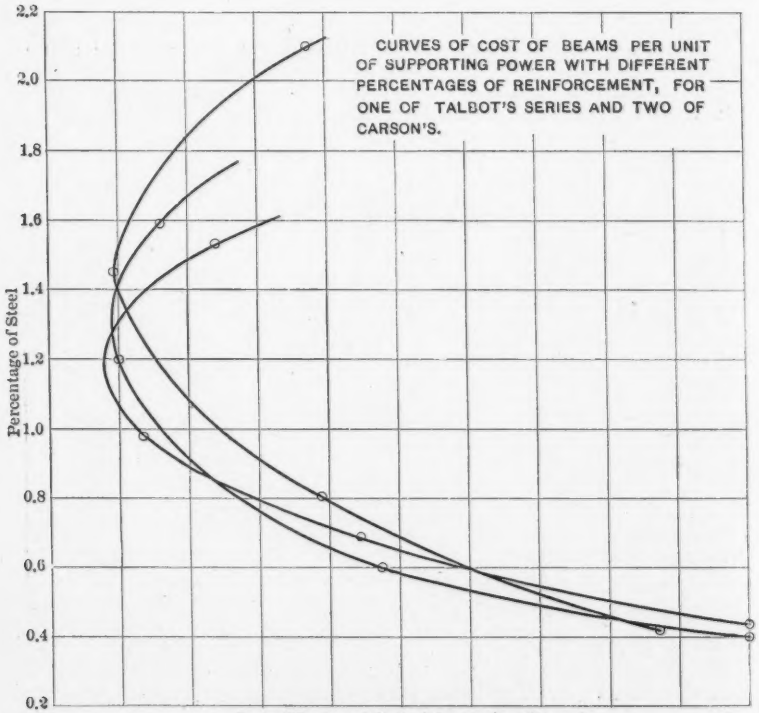



FIG. 25.

20 cents per cu. ft. for concrete and 3 cents per lb. for steel. These are the cost prices assumed by the author.

With respect to possible economies which might be effected by introducing steel in the compression edge of the beams without using it in the web also, only the tests for the Boston Tunnel shed any light, as far as the speaker is aware. However, they entirely bear out the author's deduction, that "single reinforcement" will be

cheaper. The left-hand portion of Fig. 26 shows the results ob- Mr. Goodrich.
tained, and little increase in supporting power is observable, probably because all beams will fail, by so-called "shear" in most cases, long before the top reinforcement rods can be brought into action, unless special means are provided to make them do so.

From some experiments on the longitudinal reinforcement of columns which the speaker has seen, he feels certain that, in both beams and columns, steel designed to take compression, under such conditions, carries but a small percentage of what it is usually calculated to do. If it is necessary to increase the compression side of a girder with steel, it can be done much more economically in other ways, the beam described earlier, which broke with an extreme fiber stress of more than 2 750 lb. per sq. in. tends to prove this.

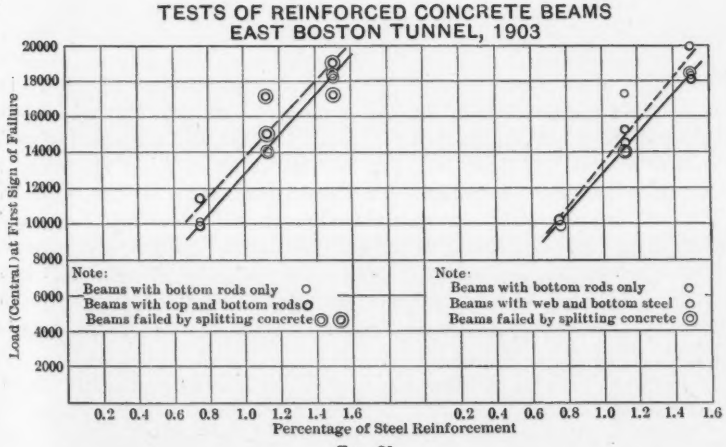



FIG. 26.

The author's paragraph with regard to the ideal web reinforcement should be fruitful of interesting discussion. Personally, the speaker does not agree with most of the clauses contained in it. However, he believes thoroughly in web reinforcement, and that it should consist of a multiplicity of small members which should extend to the top of the beam. The experiments made for the Chicago, Milwaukee and St. Paul Railway by Mr. J. J. Harding, and reported to the Western Society of Engineers, strongly tend to prove each of these items, but especially the first and last; while other experiments witnessed by the speaker some years ago led him to the conclusion contained in the second point, to which he called attention in his discussion of Captain Sewell's paper* before the International En-

*Transactions, Am. Soc. C. E., Vol. LIV, Part E, p. 459.

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gineering Congress. In the other points, issue is taken with this paper; however, these matters are not necessary to the analytical treatment, the results of which are believed by the speaker to be essentially correct and to be borne out by experiment.

In exact accord with the author's ideas, the speaker designs beams primarily with regard to the maximum moments, without reference to anything except an approximate dead load. The latter is usually taken as 1 lb. per sq. in. of "guessed-at" cross-section per foot of length. Afterward, web reinforcement is added, and all the parts thus determined are investigated as to other possibilities of failure.

The best comparative experiments known to the speaker, illustrating the value of web reinforcement, are those made by Mr. Harding, to which reference has been made. He found that his web reinforcement increased the carrying power of the beams which contained it about 50%, and that the variation in strength was much less in beams with web reinforcement than in those without it. Mr. Harding experimented with only a single percentage of steel. In some tests for the Boston Tunnel, a wide variation in the percentage of tension reinforcement was made. The same relative effect of web reinforcement was observed, but no results as striking as those of Mr. Harding were obtained. In the curves shown at the right of Fig. 26, beams with bottom rods without web steel are compared with those with bottom rods and with vertical web reinforcement. The value of the latter will never be apparent until the load has reached a point beyond which the concrete cannot withstand the developed stresses. In Professor Talbot's discussion of Mr. Harding's paper, this value is given as:

Vertical shear $\div$ (breadth $\times$ effective depth) = from 125 to 150 lb. per sq. in.

It is well known that when conditions are right, concrete can develop a very large shearing resistance, and the speaker believes that properly designed beams should take account of this capacity. In this point he differs from the author, who states that "ideal web reinforcement" should be of such size that "the sum of the horizontal components of the stresses in all the web members in each half of the beam should be at least equal to the maximum stress in the flange reinforcement." The speaker believes that this would give an excessive amount of web steel.

Turning to the Boston experiments, it is seen that the beams provided with web steel show little improvement over beams without it, until a point is reached above which the latter beams fail by "shear"; but, even then, only small improvement is found, due probably both to the design of the web reinforcement and the relative depths of the beams.




FIG. 1.—BEAM TESTED FOR BOSTON TUNNEL, WITHOUT STIRRUPS, SHOWING TYPE OF FAILURE.



FIG. 2.—REINFORCEMENT USED IN BRICK BEAM TEST.



FIG. 3.—BRICK BEAM, NOT LOADED.

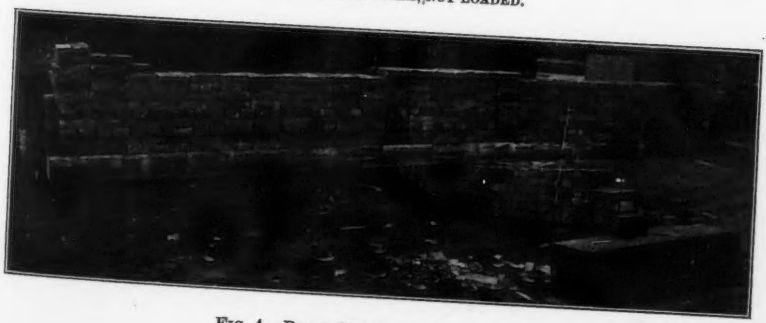


FIG. 4.—BRICK BEAM SUPPORTING LOAD.

When comparison is made between beams which have both top and bottom rods, with and without web reinforcement, or beams which have web reinforcement with and without top rods, a decided improvement is apparent. The results of such comparisons are shown in Fig. 27, in which, except where stated to the contrary, loadings are given at the first sign of failure. When ultimate loads are considered (at which the speaker usually looks askance), a still more striking improvement is apparent. It should also be noted

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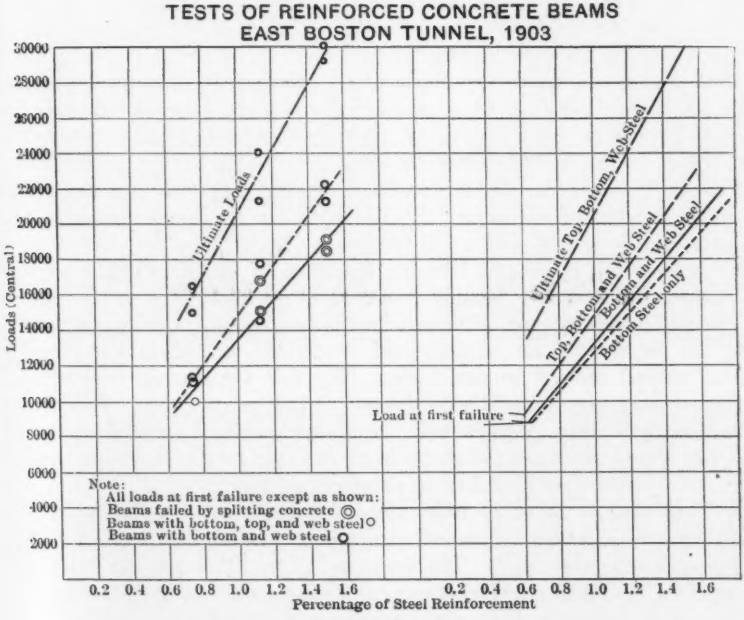



FIG. 27.

that the results given for Mr. Harding's experiments refer to loads at ultimate failure.

Unless a large percentage of tension steel is used, and the beams are comparatively deep, it will not usually be found financially profitable, purely from the point of view of increased safe load capacity, to use web reinforcement; and, even with large percentages of tension steel, it is rarely profitable unless the increase in the ultimate loads is noted, and advantage is taken to reduce the required factor of safety accordingly.

But, laying aside all ideas of economy, the speaker believes emphatically in the use of ample web reinforcement, because of the

Mr. Goodrich. marked difference in the type of failure which will take place. Fig. 1, Plate XXVIII, shows a beam from the Boston series which was reinforced with bottom and web steel and carried more than 19 000 lb. at the first sign of failure. Even when ample factors of safety are used, it is well worth the cost of web reinforcement to be sure that when failure does occur it will be like Fig. 1, Plate XXVIII, rather than like Fig. 1, Plate XXVII.

It was from a study of such conditions as are shown in the case of top rods with web steel that the speaker was led to adopt, for his work, a type of web reinforcement which did not depend for its action on its adhesion to the concrete. That is the only means that most systems have of transmitting stresses from the web steel into the concrete, whether the web steel takes the form of straight spines, or consists of vertical or other shaped members primarily designed as aids to easy construction. A much better form, in the speaker's opinion, is one in which the web steel is actually bound to the floor slab reinforcement. In this case, however, the latter should run across the top of the beam. But still better for construction purposes is a design in which the tension rods are placed in pairs, and the web steel is shaped like an inverted **U** with the free ends wrapped around the tension rods. The speaker claims no originality for this design, although he believes he was among the first to see clearly its mechanical and constructional advantages, and first worked out its proper design. By this system, the web steel may or may not be rigidly connected to the tension rods. In some beams, rigid connection is well, especially where the reinforcement is fabricated at a point distant from the point of installation, and the amount of handling during shipment is large.

The speaker must include himself among those to whom the author refers, and who cannot agree with him that "attached web members are necessary." The speaker believes that the two following tests, devised and carried out under his direction, go far toward disproving the need of the rigid attachment of web members.

A "truss" was built, consisting of tension bars hooked at the ends and of inverted **U**-shaped stirrups with their ends simply wrapped around the tension rods. The stirrups were spaced so that ordinary hard building brick could be placed between them. Flat plates were set in front of the bent ends of the tension rods to prevent the end bricks from being cut by the rods, and oak spacing pieces, of just the thickness of the stirrups, were used to separate the bricks which would otherwise rest against the stirrups and be cut by them. Figs. 2, 3 and 4, Plate XXVII, show the plain reinforcement, the brick beam, and the load carried when the top bricks began to crush, respectively.

A more interesting experiment lately carried out by the speaker was the following:

PLATE XXVIII.
PAPERS, AM. SOC. C. E.
MARCH, 1906.
GOODRICH ON
REINFORCED CONCRETE.



FIG. 1.—BEAM TESTED FOR BOSTON TUNNEL, WITH STIRRUPS AND BOTTOM RODS, SHOWING TYPE OF FAILURE.



FIG. 3.—BEAM, 14 DAYS OLD, TESTED BY WRITER. FAILED BY COMPRESSION. NO CONCRETE AROUND TENSION RODS. STIRRUPS USED.



FIG. 2.—BEAM, 14 DAYS OLD, TESTED BY WRITER. FAILED BY PULLING OUT OF HOOK. NO STIRRUPS USED.



FIG. 4.—SAME BEAM AS FIG. 2. TIPPED UPSIDE DOWN TO SHOW ATTACHMENT OF STIRRUPS, AND ABSENCE OF ALL ADHESION.

Mr. Goodrich.

A concrete beam was moulded which was reinforced with a truss similar to that used in the brick beam. However, the concrete was not allowed to get below the bottom rods except at the points of support. In this way no possibility of any adhesion between the tension rods and the concrete existed. Furthermore, there was no rigid connection between the bottom rods and the stirrups, as the latter were simply wrapped around the former. At an age of 10 days the beam failed by crushing at the center, with a load of 9 326 lb., while a similar beam, built without stirrups, failed under a center load of 9 000 lb. by rods pulling out of the concrete. Fig. 2, Plate XXVIII, shows the latter beam, and Fig. 3, Plate XXVIII, shows the failure of the beam which had stirrups, but had no concrete under the tension rods. Fig. 4, Plate XXVIII, shows the beam tipped upside down after it had been broken, so as to show the method by which the stirrups were attached to the tension rods.

The design of web reinforcement adopted by the speaker also materially increases the resistance which the beam will develop to compression, as it acts in a manner similar to that of the hooping or spiral steel used to reinforce columns. Moreover, the increased crushing strength is developed in both beams and columns, with only a fraction of what is required where longitudinal rods are used, as the tests of Considère tend to prove.

The test described earlier in this discussion, in which was developed an extreme fiber stress of from 2 750 to 3 700 lb. per sq. in. for concrete 14 days old, is a strong proof of the advantage claimed.

Whenever possible, of course, recourse is had to the device of using the floor structure adjoining the compressed edge of beams to increase the compression area of the beam, but the speaker has never been satisfied as to the accuracy of the methods of computation thus far published for such beams. It is something of a disappointment that the author did not give some analysis of the relations which should exist between his quantities, $s$, $b$ and $c$, in T-beams. He takes for granted a predetermined relation which is not involved in the determinations of economic dimensions, and perhaps he is right. In this point, it is concluded that he uses the same methods of determining the quantities in question as he gave in his paper before the International Engineering Congress, in which he followed A. L. Johnson, M. Am. Soc. C. E. It is a great pity that so few experimenters have tested beams of T-section, because they are the ones oftenest encountered, and every designer makes large use of the flanges of the T in his designs.

The analysis of the several hundred beams examined by the speaker has convinced him that reinforced concrete beams designed with vertical stirrups like those shown in Fig. 2, Plate XXVII, may

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be analyzed like a multiple-system Howe truss, as far as most points in the design go. He is borne out in this idea by three tests of full-sized members which were executed during the past year in connection with the construction work going on under his direction.

The floors for one building were designed to carry a load of 800 lb. per sq. ft. at the first crack, when 30 days old. Two full-sized modified T-beams were broken at an age of 14 days. They were designed for the building work as partially anchored at the ends, so that the denominator in the moment formula was 10 instead of 8, as for beams simply supported at the ends, and as the tests necessarily must be. Rails were loaded upon the test beams, and their weight was sufficient to cause failure without the possibility of arching or of other troublesome effects. The actual load safely carried by the tests when the first cracks appeared, when increased in the ratio of 10 to 8, was equivalent to a load of 815 lb. per sq. ft.

Four months after one floor of the building had been completed, four full bays, aggregating a total area of about 1 000 sq. ft., were loaded with brick to aggregate 875 lb. per sq. ft. Under this load, a fine crack appeared at the center of the bottom of the two fully-loaded girders, with no signs of strain visible at any other point except small deflections. Great care was taken to pile the brick so as to prevent any arching effect, and, as the greatest deflections were slightly more than $\frac{1}{4}$ in. for 17-ft. spans, little reduction of load from arching could have occurred in any case.

The third test was of a beam designed to carry a central load, and illustrates two important points, in spite of the fact that the concrete was of very inferior quality, for some reason as yet unfathomed by those in charge. Figs. 1 and 2, Plate XXIX, show the beam as a whole, and a near view of the principal failure. Just as the last rail was applied to the test, tension cracks appeared near the center of the beam. At almost the same time, spalling of the concrete took place at the top, at the center. This might have been hastened by the action of the load, but only slightly so, as good supports were provided to distribute the load properly. Before another rail could be added, the failure shown in the photograph took place. It is one in which a whole panel between two of the vertical stirrups seemed to shear out (using the word in its proper sense). There was no indication of failure by diagonal tension, according to the usually accepted idea of shear; and the failure cannot be attributed to horizontal shear, as the structure of the exposed concrete shows that the stresses were solely vertical ones. In this connection, it should be noted that most designers give the horizontal steel its full value in resisting vertical shear. It is believed that this method of design is proved to be of doubtful value by this experiment.

One point, clearly brought out, is that a type of failure, which

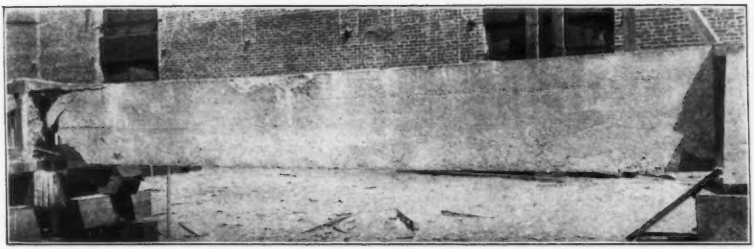


FIG. 1.—BEAM WHICH FAILED BY TENSION, COMPRESSION AND END SHEAR, SIMULTANEOUSLY.

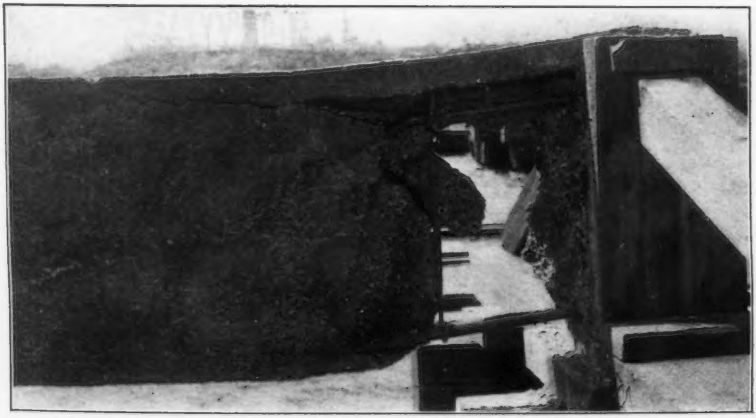


FIG. 2.—VIEW SHOWING CHARACTER OF FAILURE DUE TO END SHEAR.

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has not generally been considered, is possible when numerous stirrups are used. There was no pulling out of the bottom rod from the concrete at the point of support, and there was perfect action between the concrete and the unattached stirrups in this case. The failure occurred in the first panel away from the abutment, and at a load far less than the longitudinal steel would carry theoretically in shear.

One special point, from which the speaker draws some consolation with regard to this test, is that the quantities assumed in making up the design were so well balanced that the three principal types of failure showed themselves almost simultaneously. This shows that all parts of the structure were consistently proportioned and that, with safe loads, all parts would have equal factors of safety. Of course, with better concrete, this relation would not be quite so close, but then failures would have taken place through tension, and the other parts would have been very near failure as well. Of all types, a failure by tension is least to be feared, as the author intimates. However, only in beams with very low percentages of reinforcement will failure occur without a considerable crushing occurring after the steel has passed its elastic limit.

The speaker believes that the type of reinforcement he has adopted is far cheaper than that advocated by the author, and will be even more efficient in some cases. The experience of the past year, during which several thousand tons of such reinforcement were fabricated and worked into place under the speaker's direction, has shown that steel fabricated and ready for placing costs only about $45 per ton, and that the cost of placing in the forms is less than ¼ cent per lb.

When the author discusses the advantages of rigid attachment of web members, in regard to fire tests, he makes a statement about "web members wrapped around the tension bars" being inadequate. To this the speaker takes exception, and he feels that the test of the concrete beam illustrated in Figs. 3 and 4, Plate XXVIII, tends to prove the fallacy of the author's statement.

The speaker thoroughly agrees with the author in all that he says in his conclusion about the advantages of having web reinforcement run quite to the tops of beams, but he would substitute the word "vertical" for "diagonal" in each case.

The speaker has been intensely interested in this subject for a long time, but feels that there is more experimental work available for analysis than the author admits in his last paragraph.

This opportunity is taken to give expression to a gradually growing feeling, on the speaker's part, that much of the analytical work now in vogue is based on wrong primary assumptions. At least one writer of a book on the subject of reinforced concrete has hinted at

Mr. Goodrich. the same thing, and an engineer of some eminence has lately broached the same idea in a paragraph of a public address which has been printed in an engineering periodical.

In any case, the thanks of the profession are certainly due to Captain Sewell for his timely and scholarly paper.

Mr. Thacher. EDWIN THACHER, M. AM. SOC. C. E. (by letter).—The writer has no doubt that the author's Equation 0 will give as reliable results as any other formula, however complicated, provided the values, $h$ and $A$, are well established.

As noted by the author: "$A$ must be expressed as some fraction of the area of concrete." $A$ should bear such relation to $d$ that the strength of the concrete in compression is equal to the strength of the steel in tension. If, in Equation 0, the values of $A$ and $T$ be substituted, it becomes $M = h\ d^2$, which is simpler still, and this is the formula giving the moment of resistance of a rectangular concrete-steel beam which has been used quite extensively by the writer and others for the past six years. It was first published in the *Transactions* of the Association of Civil Engineers of Cornell University,* and, since then, has been published in *Cement*,† in *Engineering News*,‡ and in a pamphlet issued by the Concrete-Steel Engineering Company, and is quite well known. In the same publications, formulas are given for the ultimate strength of beams, supported at the ends and loaded at the center, in terms of $\frac{d^2}{l}$; for beams uniformly loaded, in terms of $\frac{d^2}{l^2}$; and for finding the depth of beam to sustain any required load, $l$, being known. Nothing simpler is possible or could be desired. They are in the same form, and require no more labor in calculation than formulas for wooden beams.

In the writer's formulas, the stress-strain line is considered as straight, but, if considered as a parabola or any other curve, the only change in the formulas will be in the value of the constant coefficient, and if this is established by experiment it does not matter what shape of stress-strain curve is usual in calculation.

In the formulas above noted the constant coefficients were determined theoretically. The ultimate strength of the concrete and steel were used; also such values of $E_c$ as resulted from the highest pressures recorded. From the results of such tests as the writer has been able to work up, he has had no occasion to change the values of the coefficients. Five sets of tests, made in different localities, and by different men, cover a variation in composition of concrete from 1:2:4 to 1:3:6, a variation in age of specimens from 23 to 90 days, a variation in ratio of length to depth of 6.0 to 22.2, a variation in

* Vol. X, 1902.
† July, 1902.
‡ February 12th, 1903

Mr. Thacher.

strength of metal from 50 000 to 100 000 lb. per sq. in., and a variation in percentage of metal from 0.31 to 3.9 per cent. The maximum variation between actual and estimated strength in no case exceeded 16 per cent. The mean variation for any one set of tests in no case exceeded 2.3%, and the mean variation for all tests, 30 in number, was 0.013%, or practically zero.

In 9 of the 30 tests the reinforcing bars broke. The writer does not see how any formula for ultimate strength of concrete-steel beams can be even approximately true when the elastic limit of the steel is used in the formula, unless the constant coefficient is modified to compensate therefor.

The elastic limit of steel is about six-tenths of its ultimate strength. Considère and Professor Bach state that the elastic limit of concrete, as far as concrete can have an elastic limit, is also about six-tenths of its ultimate strength in compression, so that it appears to the writer that if the author uses the elastic limit of steel in his formulas he should use 60% instead of 80% of the crushing strength of the concrete. The writer agrees with the author that it would be very desirable to make numerous tests of beams using, say, 1:2:4 and 1:3:6 concrete, and containing various percentages of steel reinforcement, for the special purpose of establishing the values of $h$ in his Equation 0, or the coefficient of $d^2$ in the writer's formula. From the result of Professor Hatt's experiments, the writer drew the conclusion that if the amount of reinforcement is double what it should be to equal the strength of the concrete the gain in strength of beam due to lowering the position of the neutral axis will be about 20%, and if the value of $E_c$ is doubled there will be a loss of strength of about 20 per cent. The writer agrees with the author that the safe loads should be determined by a factor of safety, for the breaking loads can be found by tests, and, for any intermediate loads, the value of $E_c$ is constantly changing. He does not agree with him, however, regarding the factor of safety recommended, that is to say, nothing for dead load and 4 for live load. If there is anything that will ultimately bring concrete-steel construction into disrepute the writer believes it will be due to the reckless method of proportioning followed by some constructors. The writer never heard of a bridge or an arch being designed with a factor of safety of 1 for dead load, and the engineer who would undertake it would probably not repeat the experiment. The writer believes that if cost prohibits a factor of safety of at least 3 for both dead and live loads it will be better to use wood or some other cheap but safe construction. The investigations and formulas of the author regarding minimum cost are interesting and instructive, but the writer doubts whether they will find much practical application, as the depth of beams is frequently governed by practical considera-

Mr. Thacher. ations, and the minimum percentage of steel is fixed by calculation, and any greater amount than that is partially wasted. The writer does not agree with the author that the attachment of the web reinforcement to the horizontal reinforcement should necessarily be independent of the concrete. As long as the web reinforcement is attached to the flange reinforcement, and is securely clamped thereto by the concrete, no movement can take place, and all conditions are satisfied.

If, as the author considers, it is necessary to provide steel for all shearing stresses, it appears to the writer that all superfluous parts of the concrete should be removed, resulting in what is known as the Visintini system, which the writer considers a very excellent system, it being the application of the truss principle to concrete-steel construction.

# MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

## ANTHONY HOUGHTALING BLAISDELL, M. Am. Soc. C. E.*

DIED SEPTEMBER 9TH, 1905.

Anthony Houghtaling Blaisdell was born at Coeymans, Albany County, New York, on December 23d, 1848. He had some of the best Dutch blood in the country in his veins. On his mother's side he was descended from Colonel Anthony Van Bergen (an officer in the Revolutionary War) and on his father's side from Levi Blaisdell, of Amesbury, Mass., who entered the Revolutionary Army at sixteen years of age as Ensign, and who, at the close of the war, settled in Coeymans, where his descendants still possess a part of the old land grant from Charles I.

Mr. Blaisdell entered Rensselaer Polytechnic Institute, at Troy, New York, at the age of eighteen, and was graduated therefrom with high standing in the class of 1870. In September of that year he entered the service of the United States in the Engineer Department, with which, to a greater or less extent, he was identified during all his subsequent career. His work was largely upon the Mississippi and its tributaries, and, during the greater portion of the time, his headquarters were in St. Louis, Missouri. He rendered important service upon the construction of the Des Moines Rapids Canal, and surveyed and helped carry on improvements on several inland rivers west of the Mississippi. In particular, he was connected for many years with the improvement of the Missouri River and its important tributary, the Osage.

Mr. Blaisdell was an expert boat builder, especially skilled in the ironwork of snagboats and other craft connected with river improvement work, and several of these important boats were built from his designs.

During the greater part of his service with the Government he was the Principal Assistant of Colonel Charles R. Suter, Corps of Engineers, U. S. A. He also served with Colonel Amos Stickney, and to a less extent with other officers of the Corps of Engineers.

In 1879 Mr. Blaisdell went into the private business of boat building in St. Louis, under the firm name of Allen and Blaisdell, and continued in this business until 1885. Owing to various causes, this undertaking did not prove successful, and Mr. Blaisdell re-

*Memoir prepared by H. M. Chittenden, M. Am. Soc. C. E.

turned to the Government service in the latter year. While engaged in private business Mr. Blaisdell was a most active and useful citizen in both educational and philanthropic lines, serving for three years on the St. Louis Board of Education and leaving everywhere marks of his accurate and organizing mind, no detail being too small to be carefully weighed and its value determined.

In his professional career in the service of the United States Mr. Blaisdell was one of its most trusted employees. He was a man of absolute truthfulness and integrity of character, an earnest and industrious worker, loyal to his superiors, and, all in all, one of those men who make it possible for their employers to accomplish important work. Sincerity marked every act of his life. He was not an ambitious man, in the sense of endeavoring to reach beyond the positions which seemed naturally to fall to his lot, and, whether or not his situation promised him advancement, it made no difference in his fidelity to duty. He was thoroughly beloved by all his employers, and was never lacking a position in the Government service as long as his health permitted him to retain one.

In 1878 Mr. Blaisdell married Miss Mary McConnell, of Chicago, who still survives him. This union was blest with two children, one of whom, Mr. Robert Van Bergen Blaisdell, survives him.

Owing to declining health Mr. Blaisdell left the Government service in 1903 and returned to the parental estate at Coeymans, where he died in 1905, in the house in which he was born.

Mr. Blaisdell was elected a member of the American Society of Civil Engineers on March 3d, 1880.

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## GEORGE DRAPER STRATTON, Assoc. M. Am. Soc. C. E.*

DIED NOVEMBER 21ST, 1905.

George Draper Stratton was born in Orange, New Jersey, on June 5th, 1870. When he was one year old his father moved with his family to Newburgh, New York, where he was interested in the Washington Iron Foundry. On the death of his father, in 1876, his mother moved to Riverside, California, with her children.

At the age of 15 he was forced to leave school in order to help support his mother and sisters. This he continued to do until his mother's death, in 1887.

Mr. Stratton used the small share which he received from his mother's estate in obtaining a college education. He entered Stan-

* Memoir prepared by Charles D. Marx, E. M. Boggs, Members, Am. Soc. C. E., and R. M. Drake, Assoc. M. Am. Soc. C. E., from information furnished by Mrs. Stratton.

ford University in the fall of 1891, with the pioneer class, as a special student. By hard work he made up his entrance deficiencies, and was graduated with honor, in the course in Civil Engineering, in May, 1895.

He at once commenced the practice of his profession, and, after several minor engagements, entered the service of the Southern Pacific Railroad Company. He was Assistant Engineer on the Sacramento Division for one year, and was then made Roadmaster at Marysville. Here his health became undermined by malaria, and at the end of the year he was transferred to the Western Division of the Southern Pacific Railroad, with headquarters at Oakland, California. He remained there for six years, or until death called him, on November 21st, 1905. His record as Assistant Engineer and as Assistant Resident Engineer was excellent.

Mr. Stratton was married, on January 17th, 1899, to Miss Jeannie Gift. His wife and a daughter, four years of age, survive him.

Mr. Stratton was a devoted churchman. Two years before his death he became a vestryman of St. Andrew's Church, Oakland. By his beautiful example while occupying that office, he was a source of great help to many. Mr. Stratton was a Mason and a Knight Templar. Among his associates, both business and social, he was much beloved for his fine character and sweet temper. He was ever and always the same quiet, even-tempered man, whose sincerity and loyalty were unfailing. The profession has lost in him a good engineer; the world, a good man.

Mr. Stratton was elected an Associate Member of the American Society of Civil Engineers on October 4th, 1899.

# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

OF

# CIVIL ENGINEERS.

(INSTITUTED 1852.)

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VOL. XXXII. No. 4.

APRIL, 1906.

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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PROCEEDINGS.

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## SOCIETY AFFAIRS.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

**April 4th, 1906.**—The meeting was called to order at 8.40 P. M.; Vice-President Emil Kuichling in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 152 members and 38 guests.

The minutes of the meetings of March 7th and 21st, 1906, were approved as printed in *Proceedings* for March, 1906.

A paper, entitled "The Panama Canal," by A. G. Menocal, M. Am. Soc. C. E., was read by title, and the Assistant Secretary presented some additional written remarks by the author, and also written communications on the subject by Messrs. Clemens Herschel and George B. Francis. The paper was discussed further by Theodore Paschke, M. Am. Soc. C. E., and the author.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Carl Gustaf Frosell, Pencoyd, Pa.
Alexander Haring, New York City.
Cicero Demerit Hill, Chicago, Ill.
William Stephen Menden, Brooklyn, N. Y.
John Franklin Skinner, Rochester, N. Y.
William Fish Williams, New Bedford, Mass.

As Associate Members.

Augustus Rowley Archer, Jersey City, N. J.
Calvin Lewis Barton, New York City.
Horace Corey Booz, Philadelphia, Pa.
Charles Carroll Boyer, Kirbyville, Tex.
Wilfred Atherton Clapp, Portland, Me.
Charles Frank Class, Camden, N. J.
John Edward Conzelman, St. Louis, Mo.
Farley Gannett, Harrisburg, Pa.
Adelbert Andrew Henderson, Pittsburg, Pa.
Frank Scott Howell, Ellis Island, N. Y.
John Imboden Hudson, Portsmouth, Ohio.
Howard Elmer Hyde, Manila, Philippine Islands.
Lindsey Louin Jewel, Norfolk, Va.
Adolph Judell, Toana, Nev.
Henry Jacob Kolb, Brooklyn, N. Y.
Earl Brink Lovell, New York City.
George Franklin Pawling, Philadelphia, Pa.
William Hendry Prentice, Jr., Muskogee, Ind. T.
Benson Bulkeley Priest, New York City.
Arthur Edwin Roberts, New York City.
Henry Chandlee Turner, New York City.
Fred J Wagner, Sylvan Beach, N. Y.
George Roy Wood, Pittsburg, Pa.

As Associate.

Moise De Leon, Atlanta, Ga.

The Assistant Secretary announced:

The transfer of the following candidates, by the Board of Direction, on April 3d, 1906:

FROM ASSOCIATE MEMBER TO MEMBER.

EDWARD FULBISTER KENNEY, Philadelphia, Pa.
ELMER WAYLAND ROSS, Providence, R. I.
HARRY KENT SELTZER, Austin, Tex.
WALTER MICKLE SMITH, Dover, N. J.
JAMES KNAPP WILKES, New Rochelle, N. Y.

The election of the following candidates, by the Board of Direction:

AS JUNIORS.

On March 6th, 1906:

HARRY CLIFFORD FORD, Portsmouth, Va.
PUSEY JONES, New York City.
CLIFFORD MARSHALL KING, Rupert, Idaho.
RALPH ASHUR PIKE, Mt. Vernon, N. Y.
CHARLES ALBERT AUGUSTINE STEEGMULLER, Long Island City, N. Y.
GEORGE LINTON WATSON, Philadelphia, Pa.

On April 3d, 1906:

FRED EDWARD CALDWELL, Newton, N. J.
CHARLES LEE DOE, Elizabeth, N. J.
WILLIAM SHEPPARD FITZRANDOLPH, New York City.
FREDERICK HALL FOWLER, Slippery Ford, Cal.
HENRY LE ROY FRYER, Trenton, N. J.
WALTER LEROY HUBER, San Francisco, Cal.
JOHN ASPIN KIENLE, Wilmington, Del.
DANIEL BERNARD O'BRIEN, New York City.
CHARLEY EVANS SHIPMAN, Billings, Mont.
FORD CUSHING SMITH, New York City.
EDWARD LEE SOULÉ, San Francisco, Cal.
SAMUEL WILSON, Olean, N. Y.
GEORGE CREIGHTON WRIGHT, New York City.

The Assistant Secretary announced the following death:

DUNKIN WIRGMAN HEMMING, elected Associate Member, September 7th, 1892; Member, May 31st, 1904; died March 22d, 1906.

Adjourned.

**April 18th, 1906.**—The meeting was called to order at 8:40 P. M.; President Frederic P. Stearns in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 97 members and 20 guests.

A paper by L. J. Johnson, M. Am. Soc. C. E., entitled "A Complete Analysis of General Flexure in a Straight Bar of Uniform Cross-Section" was presented by the author.

The Assistant Secretary announced the following deaths:

HENRY WILLIAMS PARKHURST, elected Member September 5th, 1877; died April 7th, 1906.

FREDERICK APPEL HAUSMAN, elected Junior February 3d, 1903; died March 6th, 1906.

Adjourned.

## OF THE BOARD OF DIRECTION.

(Abstract.)

**April 3d, 1906.**—President Stearns in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, Messrs. Bissell, Bowman, Gibbs, Gowen, Kuichling, Noble, Schneider, and Swensson.

The territory occupied by the membership of the Society was divided into seven geographical districts, as required by Art. VII, Sec. 1, of the Constitution.*

Applications were considered, and other routine business transacted.

Five Associate Members were transferred to the grade of Member, and thirteen candidates for Junior were elected.†

Adjourned.

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* See page 142. † See page 139.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, May 2d, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Control of Hydraulic Mining in California by the Federal Government," by William W. Harts, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for February, 1906.

**Wednesday, May 16th, 1906.**—8.30 P. M.—At this meeting a paper, entitled "The Scranton Tunnel of the Lackawanna and Wyoming Valley Railroad," by George B. Francis and W. F. Dennis, Members, Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for March, 1906.

**Wednesday, June 6th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "Disposal of Municipal Refuse, and Rubbish Incineration," by H. de B. Parsons, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

**Wednesday, September 5th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "Concerning the Investigation of Overloaded Bridges," by Wilbur J. Watson, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

### ANNUAL CONVENTION.

The Thirty-eighth Annual Convention of the Society will be held at The Hotel Frontenac, Thousand Islands, New York, on June 26th to 29th, 1906.

The general arrangements for the Convention are in the hands of the following Committee:

CHARLES S. GOWEN,
JOHN W. ELLIS, MORRIS R. SHERRERD,
J. WALDO SMITH, CHAS. WARREN HUNT.

## NOMINATING COMMITTEE.

Under Article VII, Section 1, of the Constitution, the Board of Direction has divided the territory occupied by the membership into seven geographical districts for the purposes of the Nominating Committee, and now announces this division to the membership.

A map showing the new subdivision of the territory is printed on the opposite page.

*District No. 1.*—The territory within fifty miles of the Post Office in the City of New York.

*District No. 2.*—The States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut (except as included in District No. 1), and all countries in Europe and Africa.

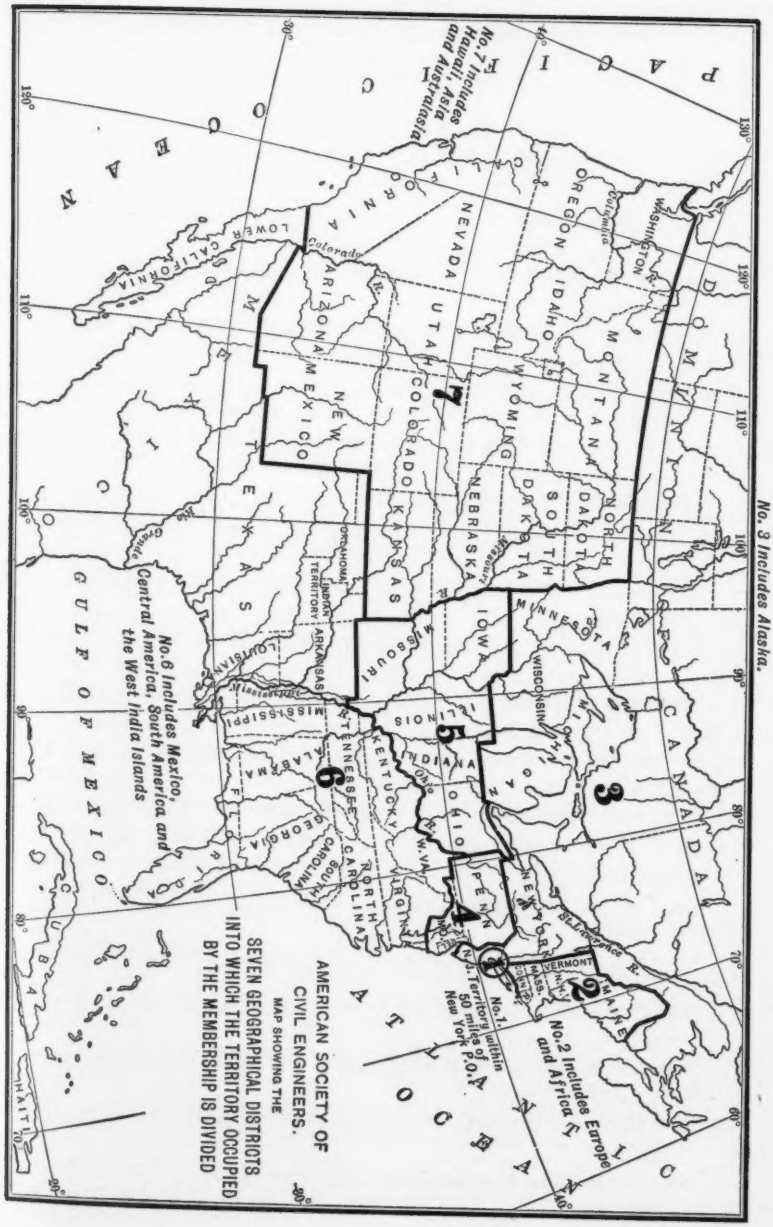
*District No. 3.*—The States of New York and New Jersey (except as included in District No. 1), the States of Michigan, Wisconsin, and Minnesota, the Territory of Alaska, and the Dominion of Canada.

*District No. 4.*—The States of Pennsylvania, Delaware, and Maryland, and the District of Columbia.

*District No. 5.*—The States of Ohio, Indiana, Illinois, Iowa, and Missouri.

*District No. 6.*—The States of Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, and Texas; the Territories of Oklahoma and Indian Territory; the Republic of Mexico; the West India Islands; and all countries in Central America and South America.

*District No. 7.*—The States of North Dakota, South Dakota, Nebraska, Kansas, Montana, Wyoming, Colorado, Idaho, Utah, Washington, Oregon, California, and Nevada; the following Territories: New Mexico, Arizona, Hawaii; and all countries in Asia and Australasia.


No. 7 Includes Hawaii, Asia and Australasia
No. 3 Includes Alaska.
No. 6 Includes Mexico, Central America, South America and the West India Islands
No. 1 N.J. Territory within 50 miles of New York P.O.
No. 2 Includes Europe and Africa
AMERICAN SOCIETY OF CIVIL ENGINEERS.
MAP SHOWING THE SEVEN GEOGRAPHICAL DISTRICTS INTO WHICH THE TERRITORY OCCUPIED BY THE MEMBERSHIP IS DIVIDED

## PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 410 Penn Avenue, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner, Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten- Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesbrough, England.

**Civil Engineers' Society of St. Paul,** St. Paul, Minn.

**Koninklijk Instituut van Ingenieurs,** The Hague, The Netherlands.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

# ACCESSIONS TO THE LIBRARY.

From March 14th to April 7th, 1906.

## DONATIONS.*

### A TREATISE ON PRODUCER-GAS AND GAS-PRODUCERS.

By Samuel S. Wyer. Cloth, 9 x 6 in., illus., 296 pp. New York, The Engineering and Mining Journal, 1906. $4.

The preface states that the first four chapters of the book are for the benefit of readers who may not be familiar with those fundamental laws and definitions of physics and applied chemistry upon which a rational discussion of producer-gas must be based. Since the engineering side of gas-producers is so closely related to applied chemistry, temperatures are stated either in Centigrade or Fahrenheit; however, as the book is intended primarily for engineers, the Fahrenheit scale is used mostly. The book contains a bibliography of gas-producers of fourteen pages, arranged chronologically. There is an index of five and one-half pages. The Contents are: Fundamental Physical Laws and Definitions; Fundamental Chemical Laws and Definitions; Thermal and Physical Calculations; Commercial Gases; Status of Producer-Gas; Classification of Gas-Producers; Manufacture and Use of Producer-Gas; Use of Steam in Gas-Producers; Carbon Dioxide in Producer-Gas; Efficiency of Gas-Producers; Heat Balance of the Gas-Producer; Fuel; Requirements; History of Gas-Producers; American Pressure Producers; American Suction Gas-Producers; Gas-Cleaning; By-Product Gas-Producers; By-Product Coke Oven Gas-Producers; Producer-Gas for Firing Ceramic Kilns; Producer-Gas for Firing Steam Boilers; Wood Gas-Producers; Removal of Tar from Gas; Gas-Producer Power Plants; Operation of Gas-Producers; Testing Gas-Producers; Future of the Gas-Producer; Gas-Poisoning; Reference Data; Bibliography.

### MÉTHODES ÉCONOMIQUES DE COMBUSTION DANS LES CHAUDIERES A VAPEUR.

Par J. Izart. Paper, 10 x 6 in., illus., 15 + 213 pp. Paris, H. Dunod et E. Pinat, 1906. 7 francs 50 centimes.

It is stated that this work continues the author's series of studies on industrial economy, and is meant to indicate clearly and simply the methods to be followed in order to realize an economy of fuel. The second part of the volume contains tables and formulas which are said to be valuable to the engineer. There are five general divisions in the contents of the book: Etude Economique de la combustion; Pertes et rendement dans la combustion; Choix d'un combustible Economique; Economie dans les méthodes de chauffe; Appareils pour le contrôle de la chauffe. There is an alphabetical index of five pages.

### A PRACTICAL TREATISE ON FOUNDATIONS;

Explaining Fully the Principles Involved, Supplemented by Articles on the Use of Concrete in Foundations. By W. M. Patton. Second Edition, Enlarged. Cloth, 9 x 6 in., illus., 28 + 549 pp. New York, John Wiley & Sons, 1906. $5.

The preface states that this edition has been enlarged by the addition of one hundred and thirty-five pages. The extensive use of concrete for foundations receives special notice and alone would justify the addition. Numerous descriptions of important modern structures are given in sufficient detail to make them understood. The index to the addition has been incorporated with the old index, and the whole is revised so that the numbers now refer to pages instead of to articles and paragraphs, as before. The index covers fourteen pages.

### THE OYSTER;

A Popular Summary of a Scientific Study. By William K. Brooks. Second and Revised Edition. Cloth, 8 x 6 in., illus., 14 + 225 pp. Baltimore, The Johns Hopkins Press, 1905. $1.

*Unless otherwise specified, books in this list have been donated by the publisher.

It is stated in the preface that this book is written for the information of all who care for oysters,—no matter whether their point of view be that of providers or consumers,—of the oysterman, the money-maker, the housekeeper, the legislator, the editor, or the student of natural history. It is the purpose of the author to help to bring about a practical and judicious system of oyster farming in Maryland, and the development and improvement of the natural resources of the waters by an account of the way in which the structure and habits of the oyster fit it for cultivation, as a submarine agricultural product. It is stated that, in this edition, no essential change seems to be necessary, and most of the new matter refers to minor points, with one exception. There has been added to the account of the structure of the oyster a section upon its peculiar fitness for gathering up the germs of cholera and typhoid fever and transmitting them to man, since, it is stated, the importance of clear ideas upon this subject increases with the growth of the cities and towns upon tidal shores, and with the increasing danger of the pollution of the oyster area by sewage. The book contains a bibliography, but there is no index.

**MAN AND THE EARTH.**

By Nathaniel Southgate Shaler. Cloth, 8 x 5 in., 6 + 240 pp. New York, Fox, Duffield and Company, 1905. $1.50 net.

The author has endeavored to set forth certain reasons why there should be a change in the point of view from which we commonly regard the resources of the earth, with the hope of directing attention to the future of the material values of the earth. The author notes that the statements concerning the mineral and other material resources are not supported by statistics in these pages, and, although the stores of value to men can be estimated in general terms, there is, as yet, no sufficient basis for accurate quantitative reckonings. The Contents are: Earth and Man; The Future of Power; The Exhaustion of the Metals; The Unwon Lands; Land from the Waters; The Problem of the Nile; The Maintenance of the Soil; The Resources of the Sea; The Changes to Come in the Human Period; The Beauty of the Earth; The Future of Nature upon the Earth; The Last of Earth and Man; The Attitude of Man to the Earth—Summary and Conclusions. There is an index of five and one-half pages.

**A HANDBOOK ON REINFORCED CONCRETE;**

For Architects, Engineers and Contractors. By F. D. Warren. Cloth, 7 x 4 in., illus., 271 pp. New York, D. Van Nostrand Company, 1906. $2.50.

The preface states that the author has endeavored to produce a reference handbook in preference to a textbook. It was the purpose to have a work treating of a general form of design rather than of a particular or patented system, but to which any of the latter may be applied. The treatment of the many phases entering the design has been carried out along well-known formulas based upon the theory of elasticity, but modified by the usual assumptions, such as the "conservation of planes" and "Hookes' Law," and not upon empirical formulas based upon experiments. Attention should be called to the fact that before applying the theory of elasticity to any particular part of the design, a sufficient number of tests were carried out along this basis to approve it, and determine the coefficients and constants. The book is divided into four parts: Part I gives a general but concise rêsumé of the subject from a practical standpoint, bringing out some of the difficulties met with in practice, and suggesting remedies. Under Part II is compiled a series of tests. Part III contains tables from which it is hoped the designer may obtain all necessary information to meet the more common cases in practice. Part IV treats of the design of trussed roofs from a practical standpoint. There is a table of contents, but no index.

Gifts have also been received from the following:

Alaska Mexican Gold Min. Co. 2 pam.
Alaska United Gold Min. Co. 1 pam.
Am. Gas Light Assoc. 1 bound vol.
Am. Mosquito Extermination Soc. 1 vol.
Am. Ry. Eng. and M. of W. Assoc. 1 pam., 1 vol.
Am. Street and Interurban Ry. Eng. Assoc. 1 vol.
Assam, India—Public Works Dept. 1 pam.
Augusta, Ga.—Mayor. 1 vol.
Baker, I. O. 1 vol.
*Beton und Eisen.* 1 pam.
Binghamton, N. Y.—Board of Water Commrs. 3 pam.
Brinckerhoff, A. G. 1 pam.
Brit. Fire Prevention Comm. 1 pam.

Burlington, Vt.—City Clerk. 1 vol.
Burlington, Vt.—Water Dept. 1 pam.
City Club of New York. 10 pam.
Civil Engrs'. Club of Cleveland. 1 pam.
Columbus, Ohio—Board of Public Service. 1 bound vol.
Columbus, Ohio—Sewage Testing Station. 4 pam.
Cumberland Valley R. R. Co. 1 pam.
Delaware & Hudson Co. 1 pam.
Eng. Assoc. of the South. 1 vol.
Eng. News Publishing Co. 18 bound vol., 6 vol., 2 pam.
Farley, G. P. 3 vol.
Fitchburg, Mass.—City Engr. 1 pam.
Francis, G. B. 1 pam.
Ginn & Co. 1 pam.
Glasgow & South-Western Ry. Co. 1 pam.
Graham. 1 pam., 8 sheets.
Grand Rapids & Indiana Ry. Co. 1 pam.
Great Britain—Under Secretary of State for India. 6 vol., 19 pam.
Green Bay & Western R. R. Co. 1 pam.
Holman, M. L. 1 pam.
Indiana, Illinois & Iowa R. R. Co. 1 pam.
Inst. of Gas Engrs. 1 bound vol.
Jamaica, West Indies—Public Works Dept. 1 pam.
Kgl. Tech. Hochschule zu Aachen. 1 pam.
Lake Shore & Mich. Southern Ry. Co. 1 pam.
Leominster, Mass.—Water Board. 1 pam.
Little Falls, N. Y.—Board of Public Works. 1 vol.
Madras, India—Irrigation Branch of Public Works Dept. 1 bound vol.
Madras, India—Public Works Dept. 1 pam.
Maine—Commr. of Highways. 1 bound vol.
Mass.—Bureau of Statistics of Labor. 1 bound vol.
Mass.—Charles River Basin Comm. 1 vol.
Mass.—Highway Comm. 1 bound vol.
Merchants' Exchange of St. Louis. 1 vol.
Mich. Central R. R. Co. 2 pam.
Min. Soc. of Nova Scotia. 1 vol.
Missouri Pacific Ry. Co. 1 pam.
National Board of Fire Underwriters Committee of Twenty. 2 pam.
National R. R. Co. of Mexico. 1 pam.
New Bedford, Mass—Supt. of Streets. 1 pam.
New Jersey—Commr. of Public Roads. 1 bound vol.
New South Wales—Govt. Statistician. 1 pam.
New South Wales—Public Works Dept. 1 pam.
New York City—Board of Health. 1 vol.
New York—State Engr. and Surv. 1 pam.
Newberry, S. B. 2 pam.
North, E. P. 12 pam., 2 bound vol., 7 vol.
Northern Central Ry. Co. 1 pam.
Ontario, Canada—Registrar Gen. 1 vol.
Pennsylvania R. R. Co. 1 pam.
Pennsylvania Univ. 1 vol.
Platt, T. C. 1 vol.
Soc. of Naval Arch. and Marine Engrs. 1 pam.
Union Coll. 1 vol.
U. S. Bureau of Labor. 1 vol.
U. S. Bureau of Soils. 10 bound vol., 2 pam.
U. S. Bureau of Statistics. 1 bound vol., 2 pam.
U. S. Forest Service. 1 pam.
U. S. Geol. Surv. 1 bound vol., 1 vol.
U. S. Interstate Commerce Comm. 3 bound vol., 3 pam.
U. S. Lake Surv. Office. 1 map.
U. S. War Dept. 4 bound vol., 14 specif.
Waddell, J. A. L. 1 pam.
Winnipeg, Man.—City Engr. 2 pam.
Wis.—Geol. and Natural History Surv. 2 bound vol.

## BY PURCHASE.

**Lippincott's New Gazetteer**; a Complete Pronouncing Gazetteer or Geographical Dictionary of the World. Edited by Angelo and Louis Heilprin. Philadelphia and London, J. B. Lippincott Company, 1906.

**Report of the Royal Commission on London Traffic, Vols. V-VI.** London, Wyman and Sons, Limited, 1906.

**The Adjustment of Observations** by the Method of Least Squares with Applications to Geodetic Work. By Thomas Wallace Wright and John Fillmore Hayford, Assoc. M. Am. Soc. C. E. Second Edition. New York, D. Van Nostrand Company, 1906.

**Coal-Tar and Ammonia.** By George Lunge. Third and Enlarged Edition. London, Gurney and Jackson, 1900.

**Building Construction and Superintendence; Part III, Trussed Roofs and Roof Trusses.** By F. E. Kidder. New York, William T. Comstock, 1906.

**The Biographical Directory of the Railway Officials of America, 1906.** Edited and Compiled by T. A. Busbey. Chicago, Railway Age Company, 1906.

## SUMMARY OF ACCESSIONS.

March 14th to April 7th, 1906.

| | |
|---|---|
| Donations (including 21 duplicates) | 208 |
| By purchase | 7 |
| Total | 215 |

## MEMBERSHIP.

### ADDITIONS.

#### MEMBERS.

| | | Date of Membership. |
|---|---|---|
| ANDERSON, GEORGE GRAY. Cons. Engr., 501 Equitable Bldg., Denver, Colo | | Feb. 7, 1906 |
| ARANGO, RICARDO MANUEL. Div. Engr., Div. of Meteorology and River Hydraulics, Isthmian Canal Comm., Panama, Panama. | Assoc. M. | Sept. 2, 1896 |
| | M. | Feb. 6, 1906 |
| BAUM, GEORGE. Supt., The Niagara Constr. Co., Ltd., Niagara Falls, Ont., Canada.. | Jun. | Jan. 4, 1892 |
| | Assoc. M. | April 5, 1899 |
| | M. | Mar. 6, 1906 |
| COOMBS, PHILIP HENRY. Civ. Engr. and Surv., 12 Exchange Blk., Bangor, Me | | Mar. 7, 1906 |
| DABNEY, THOMAS GREGORY. Chf. Engr., Yazoo-Mississippi Delta Levee Dist., Clarksdale, Miss | | Jan. 3, 1906 |
| DAVIS, ARTHUR LINCOLN. Asst. to Pres., Am. Bridge Co. of N. Y., 42 Broadway, New York City | Jun. | April 4, 1893 |
| | Assoc. M. | Oct. 7, 1896 |
| | M. | Mar. 6, 1906 |
| DILL, HOWARD ALBERT. Engr. and Supt., Richmond City Water Works, Richmond, Ind | | Oct. 4, 1905 |
| GARLINGHOUSE, FREDERICK LEMAN. Glenshaw, Pa | | Mar. 7, 1906 |
| KENNEY, EDWARD FULBISTER. Engr. of Tests, P. R. R. Co., Broad St. Station, Philadelphia, Pa | Jun. | Nov. 3, 1896 |
| | Assoc. M. | May 3, 1899 |
| | M. | April 3, 1906 |
| LEWERENZ, ALFRED COURTNEY. Civ. Engr., U. S. N., U. S. Navy Yard, Puget Sound, Bremerton, Wash | Jun. | Mar. 5, 1895 |
| | Assoc. M. | June 6, 1900 |
| | M. | Mar. 6, 1906 |
| MURRAY, JOHN FRANCIS. 25 South 34th St., Philadelphia, Pa | | Mar. 7, 1906 |
| NORBOE, PAUL MANINGHAM. Hanford, Cal | | Nov. 1, 1905 |
| PROAL, ARTHUR BREESE, JR. 2643 Broadway, New York City | | Mar. 7, 1906 |
| SILVA FREIRE, VICTOR DA. P. O. Box 18, Sao Paulo, Brazil | | Jan. 3, 1906 |
| SKINNER, JOHN FRANKLIN. 23 Cornell St., Rochester, N. Y | | April 4, 1906 |
| SPOONER, HERMAN WINSLOW. 28 Granite St., Gloucester, Mass | | Jan. 3, 1906 |
| SWEZEY, EDWIN CHARLES. 259 Fifty-second St., Brooklyn, N. Y | | Mar. 7, 1906 |
| WILKES, JAMES KNAPP. Chf. Engr. of Sewers, City Hall, New Rochelle, N. Y | Assoc. M. | June 3, 1891 |
| | M. | April 3, 1906 |
| WILLIAMS, WILLIAM FISH. City Engr., S. E. cor. Court and Orchard Sts., New Bedford, Mass | | April 4, 1906 |

MEMBERS (*Continued*).

| | | Date of Membership. |
|---|---|---|
| WOOD, IRVING SPARROW. Asst. Engr. in Chg., Water Dept., City Engr.'s Office, City Hall, Providence, R. I. | Jun. | Mar. 5, 1890 |
| | Assoc. M. | Mar. 7, 1900 |
| | M. | Mar. 6, 1906 |

ASSOCIATE MEMBERS.

| | | |
|---|---|---|
| AIKENHEAD, JAMES RAY. Asst. Engr., Westinghouse, Church, Kerr & Co., East Liverpool, Ohio | | Feb. 7, 1906 |
| ALEXANDER, HENRY JAMES. Asst. Engr., Rapid Transit Comm., 231 West 125th St., New York City | | Mar. 7, 1906 |
| BUEHLER, WALTER. 400 Oneida Blk., Minneapolis, Minn. | | Mar. 7, 1906 |
| CLASS, CHARLES FRANK. Asst. Chf. Draftsman, Am. Coke & Gas Constr. Co. (Res., 1440 Kenwood Ave.), Camden, N. J. | Jun. | Mar. 3, 1903 |
| | Assoc. M. | April 4, 1906 |
| ESTES, FRANKLIN EDWARD. Rincon Antonio, Oaxaca, Mexico | | Feb. 7, 1906 |
| FALTER, PHILIP HENRY. Shawinigan Falls, Que., Canada. | | Mar. 7, 1906 |
| GOODELL, JOHN STANTON. Asst. Engr., G. C. & S. F. Ry., P. O. Box 472, Cleburne, Tex. | | Mar. 7, 1906 |
| HOLTZMAN, STEPHEN FORD. 11 East 24th St., New York City | | Mar. 7, 1906 |
| HOWELL, FRANK SCOTT. 2394 Seventh Ave., New York City | | April 4, 1906 |
| KEITH, CHARLES WHITESIDE. 209 Adams St., Room 62, Chicago, Ill. | | Mar. 7, 1906 |
| LEANE, WALTER BURDITT. Res. Engr., Fish River Irrigation Surveys, Fish River Station, Cape Colony, South Africa | | Jan. 3, 1906 |
| LEE, ELSWORTH MORTIMER. Care, Miller-Collins Co., 29 Broadway, New York City | | Mar. 7, 1906 |
| LEIGHTON, MARSHALL ORA. 1330 F St., Washington, D. C. | | Oct. 4, 1905 |
| LINDAU, ALFRED EMANUEL. Asst. Engr., St. Louis Expanded Metal Fireproofing Co., 606 Century Bldg., St. Louis, Mo. | | Jan. 3, 1906 |
| MUNN, ALEXANDER MAJORS. Nebraska City, Nebr. | | Jan. 3, 1906 |
| PARKER, RICHARD DENNY. Res. Engr., Houston, East & West Tex. Ry., and Houston & Shreveport R. R., Houston, Tex. | Jun. | June 3, 1902 |
| | Assoc. M. | Mar. 7, 1906 |
| ROBINSON, GEORGE LOOMIS. 1 Madison Ave., New York City | Jun. | April 5, 1904 |
| | Assoc. M. | Mar. 7, 1906 |
| STOKES, STANLEY FREDERICK. Govt. Engr., Mines Dept., Johannesburg, Transvaal, South Africa | | Oct. 4, 1905 |
| SUTTON, CHARLES WOOD. 337 Broad St., Chester, Pa. | Jun. | Dec. 1, 1903 |
| | Assoc. M. | Dec. 6, 1905 |
| THAYER, HORACE RICHMOND. 680 Ostrum St., South Bethlehem, Pa. | | Mar. 7, 1906 |

ASSOCIATE MEMBERS (*Continued*).

| | | Date of Membership. |
|---|---|---|
| WILLIAMS, ROGER BUTLER, JR. Pres., Williams & Whitman, Inc., 17 Battery Pl., New York City | Jun. | Oct. 1, 1901 |
| | Assoc. M. | Mar. 7, 1906 |

ASSOCIATES.

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|---|---|
| AMBLER, DANIEL GRIFFITH. Hotel Hamilton, Washington, D. C | Mar. 7, 1906 |
| MERIWETHER, COLEMAN. Pres. and Gen. Mgr., Lock Joint Pipe Co., 346 Broadway, New York City | Feb. 7, 1906 |

JUNIORS.

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|---|---|
| BLATCH, NORA STANTON. 17 East 26th St., New York City. | Mar. 6, 1906 |
| BONIFACE, ARTHUR. 605 East 139th St., New York City. | Jan. 2, 1906 |
| BREMER, LEWIS PAUL. Webster Ave., New Rochelle, N. Y. | Feb. 6, 1906 |
| BROWN, ARTHUR ROBERT. Care, F. B. Maltby, Cristobal, Canal Zone, Panama | Jan. 2, 1906 |
| BUSHNELL, HOWARD EMORY. 115 Elm St., Hartford, Conn | Mar. 6, 1906 |
| CADWALADER, GOUVERNEUR. Perry Bldg., Philadelphia, Pa | April 3, 1906 |
| FORD, HARRY CLIFFORD. Box 131, Portsmouth, Va | Mar. 6, 1906 |
| FRAZER, JAMES STANLEY. 56 Clark St., Brooklyn, N. Y. | Jan. 2, 1906 |
| FRENCH, ROGER DELAND. 432 N. Center St., Terre Haute, Ind | Mar. 6, 1906 |
| JONES, PUSEY. Care, N. Y. W. & B. Ry., 30 Broad St., New York City | Mar. 6, 1906 |
| KING, CLIFFORD MARSHALL. Asst. Engr., U. S. Reclamation Service, Rupert, Idaho | Mar. 6, 1906 |
| MCNEIL, ARTHUR JAMES. Box 462, Whittier, Los Angeles Co., Cal | Mar. 6, 1906 |
| PIKE, RALPH ASHUR. 145 N. High St., Mt. Vernon, N. Y. | Mar. 6, 1906 |
| REYNOLDS, LAFAYETTE CLOWE. 311 North Seventh Ave., Mt. Vernon, N. Y | Feb. 6, 1906 |
| STEEGMULLER, CHARLES ALBERT AUGUSTINE. 171 Eleventh St., Long Island City, N. Y | Mar. 6, 1906 |
| STILES, ALBERT IRVINE. Cuerpo de Ingenieros de Minas, Apartado 949, Lima, Peru | Feb. 6, 1906 |
| WATSON, GEORGE LINTON. 54 Baxter Bldg., Philadelphia, Pa. | Mar. 6, 1906 |

## DEATHS.

HAUSMAN, FREDERICK APPEL. Elected Junior, February 3d, 1903; died March 6th, 1906.

HEMMING, DUNKIN WIRGMAN. Elected Associate Member, September 7th, 1892; Member, May 31st, 1904; died March 22d, 1906.

PARKHURST, HENRY WILLIAMS. Elected Member, September 5th, 1877; died April 7th, 1906.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(March 11th to April 7th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefeuille Economique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.

(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Street Railway Review*, Chicago, 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.

## LIST OF ARTICLES.

### Bridge.

Strauss Bascule Bridges.* (15) Mar. 16.
Reinforced Concrete Arch Bridge at Peru, Indiana.* Daniel B. Luten. (13) Mar. 22.
Arch Rib Bridge of Reinforced Concrete at Grand Rapids, Mich.* George Jacob Davis. (13) Mar. 22.
The Third Street Reinforced Concrete Bridge, Dayton, Ohio.* (14) Mar. 24.
Rebuilding the Housatonic River Bridge of the New York, New Haven & Hartford at Sandy Hook, Conn.* (15) Mar. 30.
Calcul des Ponts Courbes.* M. Resal. (43) 4e Trimestre, 1905.
Note sur un Système de Pont a Arc en Charpente et a Tirants Métalliques.* M. Thiolliere. (43) 4e Trimestre, 1905.
Neue Stettiner Strassenbrücken.* Benduhn. (51) Serial beginning Mar. 3.
Berechnung des Kubikinhalts von Gewölben mit Schiefem Stirnanzug.* Alfred Wessely. (53) Mar. 16.

### Electrical.

The City of London Works of the Charing Cross, West End, and City Electricity Supply Company, Limited.* W. H. Patchell. (77) Feb.
Telephone Engineering. J. J. Carty. (42) Mar.
Some Features Affecting the Parallel Operation of Synchronous Motor-Generator Sets. J. B. Taylor. (42) Mar.
Electrolysis: Topical Discussion. (28) Mar.
The Electrical Transmission of Power over Great Distances.* S. M. Kintner. (58) Mar.
Conduit Wiring for Electric Installations. (Abstract of Paper read before the Elec. Contractors' Assoc.) (73) Mar. 2.
The Operation of Circuit Breakers and Fuses.* E. W. Marchant and F. A. Lawson. (73) Mar. 2.
The Works of Messrs. Veritys, Ltd., at Aston.* (26) Serial beginning Mar. 2.
Notes on the American System of Fuse Standardization.* Alfred Schwartz. (26) Mar. 2.
Notes on Heavy Electric Switchgear. J. Whitcher. (Abstract of Paper read before the Rugby Eng. Soc.) (47) Mar. 3.
A Study in the Design of a 500 KW. Continuous-Current Generator. Max Breslauer. (73) Serial beginning Mar. 9.
Commutation in Single-Phase Motors at Starting.* Marius Latour. (27) Mar. 10.
Paper *versus* Rubber Insulation for Electric Cables.* W. I. Tamlyn, Assoc. Am. Inst. E. E. (13) Mar. 15.

* Illustrated.

**Electrical—(Continued).**

Rotating Tower Crane for the Dublin Port and Docks Board.* (26) Mar. 16.
Two-Phase Alternators for Johannesburg Municipality.* (26) Mar. 16.
The Largest Sub-Station in the World (Toronto Terminal Station). (27) Mar. 17.
New Iron Cored Instruments for Alternate Current Working. W. E. Sumpner. (24) Mar. 19.
The Sill Electricity Works.* (12) Mar. 23.
The Shawinigan Water and Power Co.* (26) Serial beginning Mar. 23.
Charging Storage Batteries from Alternating Current Circuits.* F. B. Corey. (From Paper read before the Ry. Signal Assoc.) (18) Mar. 24.
The Houston Tex., Lighting and Power Company.* (27) Mar. 24.
The Heating Effect of the Electric Spark. Henry A. Perkins. (27) Mar. 24.
Circle Diagram of Compensated Series Single-Phase Motor. E. C. Stone. (27) Mar. 24.
Electrical Equipment of Wanamaker's New York Store.* (27) Mar. 31.
Speed Characteristics and the Control of Electric Motors.* Charles F. Scott. (9) Apr.
Simultaneous Telegraphy and Telephony.* J. C. Kelsey. (39) Apr.
Elektrizitätswerk "Feistritzhammer" des Blechwalzwerkes der Firma C. T. Petzold & Co. in Krieglach.* Gustav Witz. (53) Feb. 28.
Die Elastische Verbindung der Rotierenden Massen und Ihr Einfluss auf den Regulierorgang des Motors.* Philipp Ehrlich. (53) Mar. 9.
Versuche mit Schlagwettern und dem Schlagwetterschutz Elektrischer Antriebe. H. Hoffmann. (48) Serial beginning Mar. 24.

**Marine.**

The P. and O. Twin-Screw Steamer *Mooltan.** (11) Serial beginning Mar. 9.
Motor Boats.* Bernard B. Redwood. (29) Mar. 23.
The Development of the Torpedo-Boat Destroyer.* W. J. Harding. (Paper read before the Inst. of Marine Engrs.) (19) Serial beginning Mar. 24.
Note sur le Développement de l'Application des Turbines a Vapeur a la Propulsion des Navires.* G. Hart. (32) Jan.
Les Grands Docks Flottants.* L. Piaud. (33) Serial beginning Mar. 17.
Der Einfluss der Wassertiefe auf die Geschwindigkeit von Torpedobootzerstörern.* Harold Yarrow and W. W. Marriner. (Abstract of Papers read before the Inst. of Naval Archts.) (48) Mar. 3.

**Mechanical.**

An Investigation to Determine the Effects of Steam-Jacketing upon the Efficiency of a Horizontal Compound Steam-Engine.* A. L. Mellanby. (75) June, 1905.
The Growth of Large Gas-Engines on the Continent.* Rodolphe E. Mathot. (Tr. fr. the French.) (75) June, 1905.
The Selection of Material for the Construction of Hydraulic Machinery. Arthur Falkenau. (3) Mar.
The Fuel Value of Some Tennessee and Kentucky Coals.* Chas. E. Ferris. (Paper presented to the Eng. Assoc. of the South.) (45) Mar.
Stresses in Hoisting Ropes Caused by Various Kind of Stoppages.* John Perry. (Abstract of Paper read before the British Assoc. for the Advancement of Science. (45) Mar.
The Effect of Admission Pressure on the Economy of Steam Turbines.* T. Stevens and H. M. Hobart. (11) Serial beginning Mar. 2.
Dry Process of Generating Acetylene.* (11) Mar. 2.
Foundry Practice. William A. Bole. (From Paper read before the Pittsburg Foundrymen's Assoc.) (22) Mar. 2.
The Sentinel Steam Wagon.* (12) Mar. 9.
Principles and Practice of Core-Making. Robert Buchanan. (Abstract of Paper read before the Staffordshire Iron and Steel Inst.) (22) Mar. 9; (47) Mar. 17.
Corrosion and Its Effects in Steam Boilers.* William H. Fowler, M. Inst. C. E. (47) Serial beginning Mar. 10.
Season-Cracking of Brass and Bronze Tubing. Erwin S. Sperry. (From *The Brass World.*) (47) Mar. 10.
Foundry Moulds and Their Production. E. L. Rhead. (47) Serial beginning Mar. 10.
A Criticism of the Dessau Vertical Retort Setting and Working. Thomas Settle. (66) Mar. 13.
New Gas Plant at Springfield, Mass.* (83) Mar. 15.
Remodeled Gas Works at Charlestown, Mass.* Samuel J. Fowler. (Paper read before the New England Assoc. of Gas. Engrs.) (83) Mar. 15; (24) Serial beginning Mar. 12.
The Manufacture of Brick from Shale. (14) Mar. 17.
Gas, Oil and Petrol Engines. Henry N. Bickerton. (Abstract of Paper read before the Manchester Assoc. of Engrs.) (47) Mar. 17.

* Illustrated.

**Mechanical—(Continued).**

Experiments on Surface Condensation.* James Alex. Smith. (Paper read before the Victorian Inst. of Engrs.) (11) Mar. 23.
The Pressure of Explosives: Experiments on Solid and Gaseous Explosives.* J. E. Petavel. (19) Serial beginning Mar. 24.
An Air-Compressor Test. John Howatt. (16) Mar. 24.
Common Errors in the Use of Electric Motors for Machine Driving. W. A. Ker. (Paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (47) Serial beginning Mar. 24.
The H. W. Caldwell & Son Company's New Foundry.* (20) Mar. 29.
The Betterment of Power-Station Economy by Electric Auxiliaries. Arthur S. Mann. (9) Apr.
Oils and Other Lubricants.* Augustus H. Gill. (64) Apr.
Gas Producers for Power. Julius I. Wile. (Abstract of Paper read before the Technology Club of Syracuse.) (64) Apr.
Thermic Considerations of a Retort Furnace. D. D. Barnum. (Paper read before the New Eng. Assoc. of Gas Engrs.) (24) Apr. 2; (83) Apr. 2.
By-Product Coke Oven Plant at Camden, N. J.* C. G. Atwater. (83) Apr. 2.
Mail Conveying Apparatus at the New Chicago Post-Office Building.* (13) Apr. 5.
Comment s'Exerce l'Action de Paroi dans les Moteurs a Combustion Interne. L. Letombe. (32) Nov.
La Soudure Autogène des Métaux.* P. Dumesnil. (32) Nov.
Notes sur les Convéyeurs.* G. Richard. (37) Feb.
Essais des Moteurs à Gaz et à Pétrole. R. E. Mathot and Ch. de Herbais de Thun. (37) Feb.
Machine à Vapeur Horizontale: Systeme Harris-Corliss.* Jean Grégoire. (34) Mar.
Turbines à Vapeur "Union." L. Ramakers. (33) Mar. 3.
Die Entwickelung der Lokomobilen von R. Wolf.* Karl Heilmann. (48) Serial beginning Mar. 3.
Das Rateausche Verfahren zur Verwertung des Abdampfes von Maschinen mit Unterbrochenem Betrieb.* A. Heller. (48) Mar. 10.
Versuche zur Ermittelung der Durchbiegung und der Widerstandsfähigkeit von Scheibenkolben.* C. Bach. (48) Mar. 10.

**Metallurgical.**

The Cactus Mill at Newhouse, Utah.* Leroy A. Palmer. (45) Mar.
The Kalgurli Gold Mine: Description of the Ore Reduction Plant and Process of Reduction. Robert Allen. (From the *Monthly Journal* of the Chamber of Mines of Western Australia.) (68) Serial beginning Mar. 10.
The Garfield Smelter.* L. H. Beason. (16) Mar. 17.
A New Development in Dry Blast: The Use of Water to Lower Moisture and Make it More Uniform.* A. Steinhart. (Paper read before the Technische Verein of Pittsburgh.) (20) Mar. 22.
Description of the Ore Reduction Plant & Process of Reduction on the Great Boulder Perseverance Gold Mine.* Robert Allen. (From *Monthly Journal* of Chamber of Mines of Western Australia.) (68) Serial beginning Mar. 24.
The Baggaley Pyritic-Conversion Process. (16) Mar. 24.
The Quincy Mine Assay Office. C. W. McDougall. (16) Serial beginning Apr. 7.
Ueber die Verarbeitung Flüssigen Roheisens im Basisch Zngestellten Martinofen. C. Dichmann. (50) Serial beginning Dec. 1.
Untersuchungen über die Schmelzbarkeit von Hochofenschlacken.* Mathesius. (50) Dec. 1.
Technische Fortschritte im Hochofenwesen. Oskar Simmersbach. (50) Serial beginning Mar. 1.

**Military.**

The Applications of Electricity in the Royal Gun Factory, Woolwich Arsenal.* H. C. L. Holden. (77) Feb.
The Pressure of Explosives: Experiments on Solid and Gaseous Explosives.* J. E. Petavel. (19) Serial beginning Mar. 24.

**Mining.**

Electric Winding Machines. Paul Habets. (Tr. fr. the French.) (75) June, 1905.
Late Methods of Rib Drawing.* Elias Phillips. (Paper read before the Coal Min. Inst. of America.) (45) Mar.
The Largest Fan in Existence.* (45) Mar.
The Use of Electricity in Mines. R. G. Mercer. (Abstract of Paper read before the Birmingham & Dist. Elec. Club.) (73) Mar. 16.
How to Avoid Accidents with Electrical Machinery in Coal Mines. H. Morton Middleton. (57) Mar. 16.
Underground Haulage on Curved Roads. W. H. Phillips. (Lecture delivered before the Nat. Assoc. of Colliery Mgrs.) (22) Mar. 23.

* Illustrated.

**Mining—(Continued).**

Use of Cement for "Covering" Purposes.* Stanley Nettleton. (Paper read before the Nat. Assoc. of Colliery Mgrs.) (22) Mar. 23.
The Pressure of Explosives: Experiments on Solid and Gaseous Explosives.* J. E. Petavel. (19) Serial beginning Mar. 24.
Mono Rails in Underground Tramming.* Wager Bradford. (Abstract of Paper in *Journal* of South African Assoc. of Engrs.) (16) Mar. 24; (68) Mar. 10.
Coal Mining in the Indian Territory.* W. R. Crane. (16) Apr. 7.

**Miscellaneous.**

The Finances of Engineering. Wm. D. Marks. (3) Mar.
Geology in Relation to Engineering.* Stanley C. Bailey, Assoc. M. Inst. C. E. (12) Serial beginning Mar. 16.

**Municipal.**

Street Lighting. Haydn T. Harrison. (77) Feb.
Work with Illumination and Street Photometers.* W. E. Caton. (Paper read before the Midland Jun. Gas Assoc.) (66) Mar. 6.
The Dalrymple Report (on the Chicago Situation in Regard to St. Ry. Ownership.) (17) Mar. 17.

**Railroad.**

Superheaters Applied to Locomotives on the Belgian State Railways.* J. B. Flamme. (Tr. fr. the French.) (75) June, 1905.
The Puget Sound Electric Railway.* (72) Mar.
New Designs of Third Rail Shoe and Sleet Cutter.* (72) Mar.
The Simplon Route to Italy.* (21) Serial beginning Mar.
Cole's Compound "Atlantic" Express Locomotive; Pennsylvania Railroad.* (21) Mar.
Neasden and Northolt Railway.* Chas. S. Lake. (21) Mar.
Express Goods Locomotives, 4-6-0 Type; Great Southern & Western Railway.* (21) Mar.
Steel Cross Ties.* W. F. Miller. (58) Mar.
The Works of the English McKenna Process Company (for making new rails from old ones).* (11) Serial beginning Mar. 2.
Flatbush Avenue Terminal, Long Island Railroad.* (40) Mar. 9.
New Four-Cylinder Compound Locomotives for the Great Western Railway of England. Charles R. King. (40) Mar. 9.
Projected International Railways.* (12) Serial beginning Mar. 9.
Compound Express Locomotive, Midland Railway.* (12) Mar. 9.
Reinforced Concrete Subways on the Chicago, Burlington & Quincy Ry.* (14) Mar. 10.
Plank Road Shops, Public Service Corporation of New Jersey.* (18) Mar. 10.
Fast Passenger Locomotive for Heavy Service; Chicago, Milwaukee & St. Paul Ry.* (13) Mar. 15.
The Design of Yards for Classifying Freight Cars.* W. A. MacCart. (13) Mar. 15.
Frogs without Guard Rails.* (13) Mar. 15.
The Darlington Locomotive Shops of the North Eastern Railway of England.* (40) Mar. 16.
Heavy American Type Locomotive for the Central Railroad of New Jersey.* (40) Mar. 16.
Large Electric and Steam Locomotives. J. E. Muhlfeld. (65) Feb. 16.
The Western Maryland Extension from Cherry Run to Cumberland.* Ralph C. Davison. (15) Mar. 16.
East Altoona Engine Terminal of the Pennsylvania.* Rodney Hitt. (15) Mar. 16.
The Chicago & Eastern Illinois 1905 Improvements.* (15) Mar. 16.
Lackawanna Third Track Work at Scranton, Pennsylvania.* Hugh Rankin. (15) Mar. 16.
Building the Brooklyn Subway.* George L. Fowler. (15) Mar. 16.
Specifications for Steel Rails. (15) Mar. 16.
The Shirley Plant of the Columbia Creosoting Company (for R. R. ties).* (15) Mar. 16.
A New French Pneumatic Interlocking Machine.* (18) Mar. 17.
Selection of a Railway Bridge Paint. W. B. Parker. (Paper read before the Assoc. of M. of W. Master Painters.) (18) Mar. 17.
Competition between Water and Railway Transportation Lines in the United States. Frank Haigh Dixon. (13) Mar. 22.
Ash Handling Plants at Railway Ash Pits.* (13) Mar. 22.
Summit or Hump Yards for Gravity Switching.* (13) Mar. 22.
Single-Phase Electric Equipment for the New York Terminal Division of the New York, New Haven & Hartford R. R.* (13) Mar. 22; (14) Mar. 24.
Grade Separation at Cleveland, Ohio.* Geo. H. Tinker. (15) Mar. 23.
The New Westinghouse "K" Triple Valve.* (15) Mar. 23; (25) Apr.

* Illustrated.

**Railroad—(Continued).**

Santa Fe Standard Concrete Depots.* (40) Mar. 23.
Fireproof Ferry Structure of the Lackawanna.* (40) Mar. 23.
Reports and Discussions (on railroad equipment), Maintenance of Way Association.* (Abstract of Rept. presented at the annual meeting.) (40) Mar. 23; (18) Mar. 24; (15) Mar. 30.
Recent Belgian and German Tank Locomotives.* (40) Mar. 23.
Colorado River Crevasse: Salton Sea: Southern Pacific Tracks. (40) Mar. 23.
New Grain Elevator for the Santa Fe System at Chicago.* (40) Mar. 23.
Wabash Improvements East.* (40) Mar. 23.
The Santa Fe's Modern Timber Treating Plant at Somerville.* G. B. Shipley. (40) Mar. 23.
Chicago & Western Indiana Track Elevation at Chicago.* (40) Mar. 23.
Vandalia Track Elevation at Indianapolis.* (40) Mar. 23.
Standard Specifications for Signals, Stone Masonry Right-of-Way Fences with Wooden Posts and Bridge and Trestle Timber (adopted by the Amer. Ry. Eng. and M. of W. Assoc.). (18) Mar. 24.
Interlocking on the Lackawanna at Roseville.* (15) Mar. 30.
Pacific Type Locomotive for the Southern Railway.* (40) Mar. 30; (25) Apr.
Coal Handling in the Chicago Subway.* (14) Mar. 31.
Experimental Single-Phase Installations for the Swedish State Railways.* (17) Mar. 31.
Recent British Locomotive Engineering.* Charles Rous-Marten. (10) Serial beginning Apr.
A New Type of Round House. (39) Apr.
Kingsland Shops: D., L. & W. R. R.* (39) Apr.
South Altoona Foundries: Pennsylvania R. R.* (25) Serial beginning Apr.
Standardizing Locomotive Equipment: Canadian Pacific Ry. (25) Apr.
The Mellin Compound.* Hal R. Stafford. (25) Apr.
Riegel Water Tube Locomotive Boiler.* (25) Apr.
The Long Island Power Station of the Pennsylvania, New York & Long Island Railroad.* (64) Apr.
The Long Island City Power Station.* (20) Serial beginning Apr. 5.
A New Method of Rock Tunneling under City Streets.* Frank Richards. (13) Apr. 5.
The Pennsylvania Railroad's Extension to New York and Long Island.* (15) Serial beginning Apr. 6.
The New Bergen Hill Tunnel of the Lackawanna.* J. H. Philips. (15) Apr. 6.
Test of the Sauvage Air Brake.* Geo. L. Fowler. (15) Apr. 6.
Electric Traction on Main Line Railways in Europe. Philip Dawson, M. Inst. C. E. (17) Apr. 7.
The Pennsylvania Railroad's Extension to New York and Long Island: The Long Island City Power Station.* (17) Apr. 7; (46) Serial beginning Apr. 7.
Rapport sur les Travaux du Tunnel du Simplon. M. Jacquier. (43) 4e Trimestre, 1905.
Essais de Traction Electrique entre les Gares de la Motte-les-Bains et la Motte-d'Aveillans sur une Longeur Totale de 6k635 mètres. P. Dumas. (43) 4e Trimestre, 1905.
Les Voitures à Six Roues et la Suspension Compensatrice du Capitaine Lindecker.* Le Gavrian. (43) 4e Trimestre, 1905.
Les Oscillations du Matériel des Chemins de Fer à l'Entrée en Courbe et à la Sortie.* Georges Marié. (32) Nov.
Le Funiculaire Electrique de Nancy.* G. E. Bernardet. (32) Jan.
Note sur le Matériel de la Compagnie des Wagons-Lits à l'Exposition Internationale de Liège, en 1905.* M. Gain. (36) Mar.
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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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## DISPOSAL OF MUNICIPAL REFUSE, AND RUBBISH INCINERATION.

By H. de B. Parsons, M. Am. Soc. C. E.

To be Presented June 6th, 1906.

During the winter of 1902-03, the writer contributed to the informal discussion on "The Sanitary Disposal of Municipal Refuse."* At that time, some data were presented and a short description was given of the rubbish incinerator, built from the writer's plans, at the foot of West Forty-seventh Street, New York City. Subsequently, additional data were presented at the International Engineering Congress at St. Louis.†

The writer now contributes to the Society further data on the subject of municipal refuse, which he hopes will prove both interesting and instructive, and a description of the rubbish incinerating plant built on Delancey Slip, Borough of Manhattan, City of New York, by order of John McGaw Woodbury, Assoc. Am. Soc. C. E., Commissioner of the Department of Street Cleaning, together with a description of the adjoining electric lighting station (built by order of the Department of Bridges), which utilizes the heat pro-

* *Transactions*, Am. Soc. C. E., Vol. L, p. 95.

† *Transactions*, Am. Soc. C. E., Vol. LIV, Part E, p. 263.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

duced from the incineration of the rubbish to light the Williamsburg Bridge.

This combined plant was built by the Departments of Street Cleaning and of Bridges for the benefit of the municipality, and each department retained the writer as Consulting Engineer to prepare the plans and superintend the construction. The Department of Street Cleaning gains by having the rubbish collections reduced in bulk and transformed into ash which is valuable for land-fills, and by the improved sanitary conditions caused by completely burning the beds, bedding, and old furniture, which are often germ laden, and thus preventing them from ever returning to the city. The Department of Bridges saves in the cost of lighting the bridge by using the heat of combustion for the generation of electricity. To show how well these objects have been realized is part of the subject of this paper.

## General Data.

Portions of the data here given have been taken from the papers mentioned previously. The repetition has been made in order that the new data presented, together with the former data, may be brought into this contribution, and the whole rendered as complete as possible.

A general division and subdivision of the materials is given in Table 1. The scheme classifies the wastes of a municipality and places them in three divisions, the basis of classification being chiefly dependent upon the method of handling, as practiced by "usage and custom." The first and second divisions—the "fluid and semi-fluid refuse" and the "general refuse"—consist of that portion for which the authorities should make provision, as the people cannot be made, or entrusted, to dispose of them in a sanitary manner. The third division includes those wastes which are cared for by private or special service—either by private contract or by the parties creating the refuse. The item of dead animals, however, is a possible exception, and, in large cities, the authorities should make some provision for their removal.

As uniformity in practice is lacking, the scheme for disposal adopted in any city will not always agree with the method of division for classification as given in Table 1. Some cities provide for the disposal of only a part of the general refuse, while others care for the whole.

The general refuse, which is the subject of this paper, and for which the community should provide a method for collection and disposal, is separated into five classes:

I.—Ashes;
II.—Garbage;
III.—Rubbish;
IV.—Street-sweepings;
V.—Snow.

TABLE 1.—CLASSIFICATION OF CITY WASTES.

| | | | |
|---|---|---|---|
| City Waste Materials | Fluid and Semi-fluid Refuse | Sewage | House Sewage. |
| | | | Street, Roof and Area Drainage. |
| | | | Night Soil. |
| | General Refuse | Ashes | Steam Ashes. |
| | | | Household Ashes. |
| | | Garbage | Animal Matter. |
| | | | Vegetable Matter. |
| | | | Meat and Bones. |
| | | | Fruit. |
| | | Rubbish | Paper. |
| | | | Wood. |
| | | | Rags and Bedding. |
| | | | Leather and Rubber. |
| | | | Metals. |
| | | | Bottles, Glass and Crockery. |
| | | | Sweepings from Buildings. |
| | | Street-Sweepings | Animal Manure. |
| | | | Pavement Dirt. |
| | | | Droppings from Carts. |
| | | | Materials from Building Construction. |
| | | | Some Rubbish and Leaves. |
| | | Snow | |
| | Trade Refuse | | Cellar Excavations. |
| | | | Materials from Building Construction. |
| | | | Stable Manure. |
| | | | Market Offal. |
| | | | Slaughter-house Offal. |
| | | | Dead Animals. |

The characteristics of the general refuse divisions can be stated as follows:

*1.—Ashes.*—Ashes consist of silica, oxide of iron, potash, alumina, lime, magnesia, soda, barium, phosphorus in phosphates, sulphur in sulphates, etc., and of unburned coal.

Ashes weigh about 1 350 lb. per cu. yd., varying from 1 200 to 1 500 lb., and can be divided into two grades or classes, *viz.:* "steam-ashes" and "household-ashes."

The steam-ash is that which is obtained from coal burned under steam boilers, in those industrial works where care is taken to have

the combustion reasonably perfect. The amount of combustible in steam-ash varies from about 11 to 50%,* increasing as the size of the coal decreases and as the coal is of a less caking character. This amount of combustible in the steam-ash represents a loss of unburned coal in the ash of from 2 to 33% of the fuel. A fair general average could be assumed at 26% by weight of the ash, or at 4% of the total coal used. With mechanical stoking grates, for the small sizes of anthracites and for the anthracites of a friable nature, the amount of combustible in the ash would probably exceed the average just stated. For the ordinary anthracites, the average would approximate 30%; and for the bituminous coals, the average would be about 24 per cent. For the caking coals, the average would be excessive. The loss would also be greater than the foregoing average for coals containing large percentages of earthy matter.

Table 2 shows the percentage of combustible matter found in the ash, as reported in a number of steam boiler trials, being the percentage by difference between the ash as determined by analysis and that as recovered from the ash-pit and weighed.

The household-ash is that which is obtained from coal burned in house-heaters, ranges, stoves and open fire-places. The coal used is almost entirely of those sizes which will pass through a 4½-in. screen and over a 1¼-in. screen, with the exception of the cannel coal consumed in open fire-places. While this cannel naturally burns to a clean ash, still a large quantity falls through the basket grates; and, furthermore, as the coal is of such a soft nature, much of it, in handling, crumbles into dust and small pieces, and is thus rendered too small for household use. All this combustible portion finds its way into the ash collections. On the continent of Europe, a smaller proportion of unburned coal is found in the household-ash collections than in the United States, as the use of closed stoves for household purposes is so common. In England, the proportion is greater, on account of the numerous open fire-places.

For the past twelve years, the writer has kept a complete coal record for his private dwelling. The cannel coal dust which collected between August, 1896, and August, 1902, and which had to be discarded from the household, amounted to 8.3% of the weight of cannel coal purchased. Assuming that this cannel coal dust con-

*See "Steam Boilers," by H. de B. Parsons, p. 23.

tained 4% of true ash, then the combustible portion discarded was about 8% in addition to that which was contained in the ashes from the grates.

TABLE 2.—UNBURNED COAL IN STEAM-ASH.

| Kind of coal. | PERCENTAGE OF ASH. | | PERCENTAGE OF COMBUSTIBLE. | |
|---|---|---|---|---|
| | By analysis. | By boiler trial. | Based on ash. | Based on coal. |
| | Per cent. | Per cent. | Per cent. | Per cent. |
| * Cumberland Bitumnious | 5.0 | 7.5 | 33.3 | 2.5 |
| * Pocahontas " | 4.0 | 10.0 | 60.0 | 6.0 |
| * Cumberland " | 6.1 | 8.1 | 24.7 | 2.0 |
| * Clearfield " | 7.6 | 10.1 | 24.7 | 2.5 |
| * Cape Breton " | 7.8 | 9.4 | 17.0 | 1.6 |
| † George's Creek " | 9.0 | 10.6 | 15.1 | 1.6 |
| † W. V. Pocahontas " | 11.1 | 11.9 | 6.7 | 0.8 |
| † George's Creek " | 9.3 | 10.5 | 11.4 | 1.2 |
| † Buckwheat, No. 1, Anthracite | 17.5 | 22.5 | 22.2 | 5.0 |
| † Buckwheat " " | 16.2 | 24.9 | 35.0 | 8.7 |
| * Chestnut, No. 2, " | 12.0 | 16.0 | 25.0 | 4.0 |
| * Chestnut " " | 11.8 | 19.3 | 38.8 | 7.5 |

General average.....26 per cent.
Average, Anthracite.....30 "
" Bituminous.....24 "

* Barrus on "Boiler Tests," page 251.
† From tests made by D. S. Jacobus.

The proportion of cannel to anthracite used was 1 to 7.6 or 13 per cent. By analysis, the combustible matter in the cannel coal ashes was 21.8%, making a total combustible of about 29.8 per cent. Also, by analysis, the combustible matter in the anthracite ash was 13.4 per cent. Therefore, the real average combustible in the ash discarded from the house, which can be taken as an average of similar houses in the residential portion of New York City, amounted to 15.3 per cent.

The writer had careful analyses made in February and March, 1904, of some household ashes and of samples of ash obtained directly from some of the dumps of the City of New York, with the results shown in Table 3. Therefore, it would seem safe to state that in a city like New York, the mixed ash collections from all quarters contain from 30 to 35% of combustible matter.

All the analyses of ash were made by Messrs. Simonds and Wain-

wright, Analytical Chemists. The samples from the city dumps were made by taking a shovelful from alternate carts as they drove on the dumps during the major part of one day at a dump. The pile was mixed and quartered, and the final sample, of from 12 to 15 lb., was crushed in a mill and again quartered.

TABLE 3.—ANALYSES OF ASHES.*

| | Moisture at 102° C. | Pure ash. | Combustible matter. | Total. |
|---|---|---|---|---|
| HOUSEHOLD ASH. | Per cent. | Per cent. | Per cent. | Per cent. |
| Coal burned in a stove, anthracite, size "stove No. 2" | 0.36 | 90.81 | 8.83 | 100.00 |
| Coal burned in a hot-air furnace, anthracite, size "egg" | 0.06 | 86.50 | 13.44 | 100.00 |
| Coal burned in an open grate, English cannel, size "6-in. cubes" | 0.64 | 77.53 | 21.83 | 100.00 |
| MIXED ASHES. | | | | |
| Samples from New York City Dumps... | | | | |
| Clinton Street | 1.69 | 62.19 | 36.12 | 100.00 |
| Stanton Street | 0.80 | 67.43 | 31.77 | 100.00 |
| West Forty-seventh Street | 0.83 | 63.73 | 35.44 | 100.00 |
| Average | 1.11 | 64.45 | 34.44 | 100.00 |

* Made for the writer by Messrs. Simonds and Wainwright.

II.—*Garbage.*—Garbage is, by far, the most important division of general refuse, because it is the most difficult to handle without causing annoyance, is unsightly, and is likely to become putrescible and diffuse offensive odors. On the other hand, it has a distinct commercial value, due to the value of the by-products which may be obtained from it. Whether this value is worth saving, in practice, is still a moot question, and no unity of sentiment exists, although much has been written concerning its treatment.

Its composition differs according to the season of the year, as well as the location of the city and the character of the district from which it is collected. Garbage contains a large proportion of water, the amount varying from about 50% to more than 80 per cent. During the fruit and green vegetable seasons the amount of water is always large, while in the ordinary dwelling-house garbage in winter the amount is nearer the lower limit.

In Table 4 are given some analyses of the composition of garbage. Analysis *A* was made by the Sanitary Bureau of the Board of Health of the City of New York, in October, 1897. The sample

was taken from the garbage as received on the barges or scows for final removal, and may be considered an average of the collections from many and various sources. It was practically pure garbage.

TABLE 4.—ANALYSES OF GARBAGE.

| | New York City. A. | Brooklyn, N. Y. B. | Trenton, N. J. C. | United States. D. | England. E. | Berlin. F. |
|---|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| Water | 65.90 | 71.00 | 80.00 | 70.00 | 65.00 | 60.00 |
| Animal and vegetable solids | 25.62 | 20.00 | 16.80 | 20.00 | 24.00 | 30.00 |
| Grease | ..... | 2.00 | ..... | 3.00 | 2.00 | 2.00 |
| Paper | ..... | 7.00 | 2.40 | 7.00 | 9.00 | 8.00 |
| Rags, etc | ..... | | 0.60 | | | |
| Boxes | ..... | | 0.20 | | | |
| Mineral matter | 8.48 | ..... | ..... | ..... | ..... | ..... |
| Totals | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Fat | 7.07 | ..... | ..... | ..... | ..... | ..... |
| Total nitrogen | 0.86 | ..... | ..... | ..... | ..... | ..... |
| Phosphoric acid, $P_2O_5$ | 0.07 | ..... | ..... | ..... | ..... | ..... |
| Potash, $K_2O$ | 0.30 | ..... | ..... | ..... | ..... | ..... |

*A.* Dept. of Health, October 15th, 1897.

*B.* Report, Brooklyn Board of Health, 1896.

*C. Transactions*, Am. Soc. C. E., Vol. L, p. 128.

*D*, *E* and *F*. International Engineering Congress, St. Louis, *Transactions*, Am. Soc. C. E., Vol. LIV, Part E, p. 263.

Analysis *B* is an analysis of Brooklyn summer garbage, as stated in the report of Joseph B. Taylor.*

Analysis *C* was made by Theodore Horton, Assoc. M. Am. Soc. C. E., of garbage as collected in Trenton, N. J., during the summer of 1902. It was obtained by sorting ½-ton samples and weighing and averaging.

Analysis *D* gives the composition of average American garbage, as stated by MacDonough Craven.

Analyses *E* and *F* are quoted on the authority of Rudolph Hering, who obtained his figures from W. F. Goodrich, of London, and Messrs. Bohm and Grohn, of Berlin.

All the figures in the table are given in percentages, and do not indicate more than the relative proportions of the elements reported. The actual quantities collected in certain cities are stated later.

* Board of Health Report, Brooklyn, 1896.

Garbage, as ordinarily collected, contains some rubbish, such as paper, cans, boxes, etc. Even in those cities where a primary separation system is in vogue, this admixture of rubbish may amount to 5 or 6% or more by weight.

Pure garbage weighs about 1 100 or 1 200 lb. per cu. yd., when loosely collected.

*III.—Rubbish.*—Rubbish is discarded trash, principally, of all kinds of paper, wood, rags, mattresses, bedding, boxes, chairs, sofas, barrels, leather, old shoes, rubber, tin cans, metal scraps, bottles, broken glass, crockery and the like. It is a most heterogeneous aggregation, and contains all the household wastes that cannot be classified as ashes or garbage. Every conceivable kind of rubbish waste is discarded from the houses or found in the street-sweepings; but the distinction between these classes of refuse is that such of the material as is collected from the houses strictly belongs to the rubbish classification, and such as is obtained from the streets to the street-sweeping classification.

Rubbish, as ordinarily piled in the carts, or without extra packing, weighs from 130 to 225 lb. per cu. yd. In Boston, Mass., the average weight, as delivered at the Atlantic Avenue collecting and incinerating station, was 202 lb. per cu. yd. In New York the average weight at the Thirtieth Street dump was 143 lb. per cu. yd.; at the Forty-seventh Street dump, 141.1 lb., and at the Delancey Slip incinerator, 139 lb.

As rubbish contains the dirt and dust from sweepings, cast-away bedding and rags, it is likely to harbor germs of disease, and should be taken to the place for final disposition as directly as possible, so that dry, germ-bearing dust may not be scattered among the people of the community. In other respects, the rubbish collections may be termed clean, and are not especially disagreeable to handle.

Some analyses of rubbish are given in Table 5. The figures in the first column are measurements made by the writer in 1905, and in the second and third columns by F. L. Stearns, Assoc. M. Am. Soc. C. E., of the Department of Street Cleaning of New York City, in 1904. These figures, together with those for Boston, are the percentages by weight of the marketable portions only, that is, that portion which was picked out and sold. The remainder was valueless, and was not classified, but was composed of the same ele-

ments as mentioned, together with bedding, mattresses, furniture, etc.

The smell arising from a collection of rubbish is not offensive, and the mass does not decompose. At times the collections contain some garbage, which on decomposing gives the mass a decided smell.

Rubbish, like garbage, has an inherent value. A considerable portion of the mass can be sorted out and sold at a profit. In consequence, the collections are often picked over, for which privilege contractors can be found.

The privilege of picking the rubbish at the dumps in the Boroughs of Manhattan and the Bronx brought $71 000 for 1903. For a week in 1904 the amounts varied from $1 175 to $1 920. The collections in 1903 were 126 188 tons.

At the Atlantic Avenue incinerating plant in Boston, the amount picked out and sold averages about 25½% by weight. In New York, at the Thirtieth Street dump, the amount is about 43%; at the Forty-seventh Street dump, about 48%; and at the Delancey Slip station, about 32 per cent. The two latter places are equipped with conveyors which carry the material between the rows of pickers. At the other city dumps the amount picked out is not as large. As the Delancey Street station is equipped with an incinerating plant using the heat for steam generation, only about 30% is picked out, as the remainder is required for fuel, although with the conveyor and sorting opportunity it would be easy to pick out 50 per cent. The amount picked out varies with the market price for the paper, metals, etc.

*IV.—Street-Sweepings.*—The sweepings contain two constituents of value, namely, manure and paper. When these are mixed with the street dirt, they are valueless. If the manure could be collected separately, it might be sold for fertilizer, or be sold for the same purpose to the collectors of stable manures.

Considerable rubbish, often of the dirtiest sort, is found in public thoroughfares, where it has been thrown by a careless and shiftless population. These materials—rubbish, manure, paper, and dirt, the latter coming from the pavements and, therefore, varying with the kind in use—form the major part of the street-sweepings proper. There are some house sweepings collected in the streets, but this addition aggregates but a small part. In cities in which the streets

are lined with trees, a considerable quantity of leaves is collected in the proper season, which increases the bulk materially.

TABLE 5.—COMPOSITION OF RUBBISH.

PERCENTAGES BY WEIGHT.

| COMPONENT PARTS. | PERCENTAGE PICKED OUT AS MARKETABLE. | | | | PERCENTAGE OF TOTAL COMPOSITION. | | |
|---|---|---|---|---|---|---|---|
| | City of New York. | | | Boston. | New York. | London. | Berlin. |
| | Delancey Slip station. (Parsons.) | Thirtieth St. dump. (Stearns.) | Forty-seventh St. dump. (Stearns.) | Atlantic Ave. station. (Morse.) | (Craven)* | (Russell)* | (Bohm and Grohn.)* |
| | % | % | % | % | % | % | % |
| Stoneware | ..... | ..... | ..... | ..... | ..... | 5.0 | 33.5 |
| Rags | 4.6 | ..... | 2.78 | 0.76 | 15.5 | 3.6 | 6.3 |
| Rubber | ..... | ..... | ..... | ..... | 0.1 | ..... | ..... |
| Leather | ..... | ..... | ..... | ..... | 1.8 | ..... | 3.8 |
| Straw | ..... | ..... | ..... | ..... | ..... | 29.7 | 19.7 |
| Wood | ..... | 7.3 | 8.91 | ..... | 1.4 | ..... | 2.2 |
| Metals | 0.86 | 1.3 | 4.10 | 0.12 | 3.3 | 9.2 | 4.2 |
| Glass | ..... | 1.4 | 0.76 | 0.35 | 2.9 | 13.1 | 7.0 |
| Bagging | ..... | ..... | 0.39 | ..... | ..... | ..... | ..... |
| Carpets | ..... | ..... | 0.57 | ..... | ..... | ..... | ..... |
| Shoes | ..... | ..... | 0.39 | ..... | ..... | ..... | ..... |
| Hats | ..... | ..... | 0.03 | ..... | ..... | ..... | ..... |
| Rope and String | ..... | ..... | 0.23 | 0.12 | ..... | ..... | ..... |
| Paper | 25.4 | 33.3 | ..... | 23.90 | 75.0 | 39.4 | 23.3 |
| Newspaper | ..... | ..... | 10.94 | ..... | ..... | ..... | ..... |
| Manila | ..... | ..... | 2.64 | ..... | ..... | ..... | ..... |
| Pasteboard | ..... | ..... | 10.35 | ..... | ..... | ..... | ..... |
| Mixed | ..... | ..... | 6.16 | ..... | ..... | ..... | ..... |
| Books | ..... | ..... | 0.55 | 0.24 | ..... | ..... | ..... |
| Total marketable | 30.86 | 43.3 | 48.80 | 25.49 | ..... | ..... | ..... |
| " worthless | 69.14 | 56.7 | 51.20 | 74.51 | ..... | ..... | ..... |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*International Engineering Congress, *Transactions*, Am. Soc. C. E., Vol. LIV., Part E, Paper by Rudolph Hering, M. Am. Soc. C. E.

The sweepings are combustible. The weight varies from 800 to 1 400 lb. per cu. yd., as much depends on the dryness of the weather at the time of collection.

Table 6 gives some idea of the composition of the street-sweepings.

The writer entered into correspondence with a number of cities in order to obtain data in regard to the annual collection of general refuse. It was found that many of the cities did not make separate collections of the different classes of refuse, and that many which did make separate collections did not keep records, or if they did

keep records, did not keep them with sufficient accuracy to be of service for comparison. For instance, Louisville, Ky., published in 1903 a very elaborate report in which the collections were given in cart loads. As no reference was made to the size of the carts, or their average loading, it was not possible to classify these collections.

TABLE 6.—COMPOSITION OF STREET-SWEEPINGS.

PERCENTAGES BY WEIGHT.

| Component parts. | New York. (Craven.) | Washington. (Wiley.) | Berlin. (Vogel.) | London. (Letheby)† |
|---|---|---|---|---|
| Moisture | 37 | 35 | 39 | 35 |
| Organic matter | 31 | 20 | 23 | 36 |
| Ash | 32 | 45 | 38 | 29‡ |
| | 100 | 100 | 100 | 100 |
| Proportion of organic matter to ash | 1 : 1 | 1 : 2.2 | 1 : 1.6 | 1 : 0.8 |

* From U. S. Dept. of Agriculture "Fertilizing Value of Street Sweepings," Bulletin No. 55, Division of Chemistry. International Engineering Congress, *Transactions*, Am. Soc. C. E., Vol. LIV, Part E, Paper by Rudolph Hering, M. Am. Soc. C. E.

† In dry weather.

‡ Powdered stone and abraded iron.

Some of the cities kept a record in yardage, and, in order to transform yardage into weight, the following schedule was used:

| | | |
|---|---|---|
| Weight of garbage | 1 150 | lb. per cu. yd. |
| " " street-sweepings | 850 | " " " " |
| " " ashes | 1 350 | " " " " |
| " " rubbish | 200 | " " " " |

Table 7 gives statistics of the annual collection of general refuse, in tons of 2 000 lb.

Table 8 gives the monthly collections, in pounds per capita per day, in those cities where the records were available. This table shows some variation in regard to the amounts, which is especially noticeable in the column, "Average per day." This variation is caused, to some extent, by irregularity in classifying the collections —for instance, in some cities, rubbish and ashes are collected with the garbage—thus, in Philadelphia the record shows that the quantity of garbage per capita per day is nearly 1.2 lb., while in the other cities it varies from about 0.3 to 0.8 lb., while the ashes and rubbish collections are low when compared with the others.

## TABLE 7.—Annual Collection of City Refuse, in Tons of 2 000 lb.

| City. | Year. | Population. | Garbage. | Street-sweepings. | Ashes. | Rubbish. | Totals. |
|---|---|---|---|---|---|---|---|
| Borough of Manhattan | ..... | 1 917 676 | 184 275 | *B* | 1 405 606 | 120 434 | 1 710 315 |
| " " Bronx | ..... | 268 341 | 13 475 | ..... | 109 699½ | 5 754 | 128 928 |
| " " Brooklyn | ..... | 1 291 597 | 75 675 | ..... | 501 888½ | 39 246 | 616 809 |
| Total of three Boroughs of New York | 1903. | *A* 3 477 614 | 273 425 | ..... | *D* 2 017 193¾ | *C* 165 434 | 2 456 053 |
| Buffalo, N. Y. | June 30, 1903. | *E* 391 148 | *F* 23 803 | *B* | *F* 150 469 | *F* 15 750 | 190 022 |
| Philadelphia, Pa. *H* | Dec. 31, 1903. | *E* 1 385 549 | 301 643 | 98 044 | 425 650 | 13 975 | 834 312 |
| Milwaukee, Wis. *H* | ..... | *E* 307 854 | *K* 30 441 | ..... | ..... | ..... | ..... |
| Cincinnati, Ohio *H* | 1903. | 381 200 | 21 600 | 39 362 | 142 507 | ..... | ..... |
| Washington, D. C. | Dec. 31, 1903. | *E* 296 182 | *M* 33 664 | *L* 31 810 | *L* 83 076 | *L* 14 150 | ..... |
| Newark, N. J. *H* | ..... | *E* 272 149 | 15 152 | 33 496 | *G* 203 050 | *G* | ..... |
| Cleveland, Ohio *J* | Dec. 1, 1904. | 425 000 | 43 680 | 35 036 | ..... | ..... | ..... |
| Pittsburg, Pa. | ..... | 320 000 | *O* 47 000 | ..... | ..... | ..... | ..... |
| St. Louis, Mo. | Dec. 31, 1903. | *E* 622 350 | 62 400 | ..... | *N* | *N* | ..... |

*A.* Board of Health census, 1903.
*B.* Street-sweepings included with "ashes."
*C.* The Department of Street Cleaning estimates the weight of a cubic yard of rubbish and paper at 237 lb. F. L. Stearns, Assoc. M. Am. Soc. C. E., measured and weighed 96 loads in which 1 cu. yd. weighed 140 lb. This figure has been used in reducing the yardage to pounds, one load = 1 000 lb.
*D.* Including "steam" ashes from manufacturing plants.
*E.* United States census.
*F.* Report, Department of Public Works, Buffalo, 1903.
*G.* Rubbish and paper included with ashes.
*H.* Bureau of Street Cleaning, or Board of Public Works, 1903.
*J.* Bureau of Street Cleaning, or Board of Public Works, 1904.
*K.* Average for 1901 and 1903.
*L.* Average for 1903–1904.
*M.* Garbage for 1903; street-sweepings, ashes and rubbish averaged for 1903–1904.
*N.* Collections not made by the city.
*O.* Contractor's statement for 1903.

TABLE 8.—*(Continued.)*

| City. | Classification. | Jan. | Feb. | March. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Average per Day. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cincinnati, Ohio. *A* | Garbage | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.310 |
| | Street-Sweepings | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.566 |
| | Ashes | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2.048 |
| | Rubbish | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Totals | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2.924 |
| Washington, D. C. *A* | Garbage | 0.511 | 0.512 | 0.586 | 0.641 | 0.600 | 0.577 | 0.666 | 0.871 | 0.819 | 0.733 | 0.552 | 0.543 | 0.635 |
| | Street-Sweepings | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.597 |
| | Ashes | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1.557 |
| | Rubbish | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.264 |
| | Totals | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3.053 |
| Newark, N. J. *B* | Garbage | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.305 |
| | Street-Sweepings | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.674 |
| | Ashes | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4.189 |
| | Rubbish | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Totals | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5.168 |
| Cleveland, Ohio. *B* | Garbage | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.563 |
| | Street-Sweepings | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.451 |
| | Ashes | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Rubbish | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Totals | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Pittsburg, Pa. | Garbage | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.805 |
| | Street-Sweepings | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Ashes | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Rubbish | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Totals | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| St. Louis, Mo. | Garbage | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.549 |
| | Street-Sweepings | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Ashes | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Rubbish | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | Totals | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

☞ *A*—Report, Department of Street Cleaning. *B*—Report, Department of Public Works.

TABLE 8.—COLLECTION OF CITY REFUSE, IN POUNDS PER CAPITA PER DAY.

| City. | Classification. | Jan. | Feb. | March. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Average per Day. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New York City. Bor. Manhattan. A | Garbage | 0.354 | 0.372 | 0.477 | 0.540 | 0.567 | 0.613 | 0.596 | 0.622 | 0.628 | 0.613 | 0.505 | 0.416 | 0.525 |
| | Street-Sweepings | | | | | | | | | | | | | |
| | Ashes | 5.282 | 5.089 | 4.778 | 4.123 | 3.588 | 3.528 | 3.326 | 2.975 | 3.167 | 3.437 | 4.017 | 5.082 | 4.016 |
| | Rubbish | 0.294 | 0.277 | 0.311 | 0.345 | 0.389 | 0.391 | 0.385 | 0.351 | 0.365 | 0.377 | 0.337 | 0.317 | 0.345 |
| | Totals | | | | | | | | | | | | | 4.886 |
| New York City. Bor. Bronx. A | Garbage | 0.185 | 0.194 | 0.249 | 0.282 | 0.296 | 0.319 | 0.311 | 0.324 | 0.328 | 0.320 | 0.263 | 0.217 | 0.274 |
| | Street-Sweepings | | | | | | | | | | | | | |
| | Ashes | 2.932 | 2.833 | 2.653 | 2.294 | 1.994 | 1.962 | 1.843 | 1.651 | 1.762 | 1.912 | 2.235 | 2.892 | 2.241 |
| | Rubbish | 0.100 | 0.094 | 0.106 | 0.118 | 0.133 | 0.133 | 0.131 | 0.120 | 0.124 | 0.128 | 0.115 | 0.108 | 0.1175 |
| | Totals | | | | | | | | | | | | | 2.6825 |
| New York City. Bor. Brooklyn. A | Garbage | 0.216 | 0.236 | 0.280 | 0.330 | 0.344 | 0.374 | 0.364 | 0.380 | 0.383 | 0.374 | 0.308 | 0.265 | 0.321 |
| | Street Sweepings | | | | | | | | | | | | | |
| | Ashes | 2.783 | 2.684 | 2.520 | 2.176 | 1.892 | 1.863 | 1.754 | 1.565 | 1.673 | 1.813 | 2.121 | 2.680 | 2.127 |
| | Rubbish | 0.141 | 0.134 | 0.150 | 0.167 | 0.188 | 0.189 | 0.186 | 0.170 | 0.176 | 0.182 | 0.162 | 0.153 | 0.1665 |
| | Totals | | | | | | | | | | | | | 2.6145 |
| Buffalo, N. Y. B | Garbage | 0.244 | 0.230 | 0.268 | 0.279 | 0.299 | 0.333 | 0.389 | 0.405 | 0.486 | 0.445 | 0.340 | 0.290 | 0.334 |
| | Street-Sweepings | | | | | | | | | | | | | |
| | Ashes | 2.702 | 2.662 | 2.501 | 2.161 | 1.874 | 1.850 | 1.741 | 1.552 | 1.660 | 1.800 | 2.101 | 2.660 | 2.110 |
| | Rubbish | 0.188 | 0.178 | 0.200 | 0.222 | 0.250 | 0.252 | 0.247 | 0.226 | 0.227 | 0.242 | 0.217 | 0.208 | 0.221 |
| | Totals | | | | | | | | | | | | | 2.665 |
| Philadelphia, Pa. A | Garbage | 0.878 | 0.849 | 0.753 | 1.011 | 0.812 | 0.976 | 1.327 | 1.340 | 2.494 | 1.479 | 1.167 | 1.216 | 1 192 |
| | Street-Sweepings | 0.281 | 0.249 | 0.350 | 0.437 | 0.404 | 0.355 | 0.463 | 0.349 | 0.484 | 0.373 | 0.370 | 0.310 | 0.368 |
| | Ashes | 2.075 | 2.106 | 1.817 | 2.136 | 1.513 | 1.351 | 1.465 | 1.101 | 1.459 | 1.295 | 1.608 | 2.278 | 1.683 |
| | Rubbish | 0.071 | 0.061 | 0.047 | 0.061 | 0.052 | 0.050 | 0.058 | 0.046 | 0.062 | 0.048 | 0.049 | 0.055 | 0.055 |
| | Totals | | | | | | | | | | | | | 3.298 |
| Milwaukee, Wis. B | Garbage | 0.539 | 0.514 | 0.511 | 0.491 | 0.514 | 0.594 | 0.636 | 0.625 | 0.588 | 0.576 | 0.489 | 0.422 | 0.542 |

TABLE 8.—*(Continued.)*

TABLE 9.—AVERAGE COLLECTIONS PER CAPITA PER DAY.

| | Pounds. | Yards. | Percentage. | |
|---|---|---|---|---|
| | | | By weight. | By volume. |
| Garbage | 0.5296 | 0.000460 | 14.12 | 11.77 |
| Street-Sweepings | 0.5310 | 0.000625 | 14.15 | 15.99 |
| Ashes | 2.4960 | 0.001849 | 66.54 | 47.31 |
| Rubbish | 0.1948 | 0.000974 | 5.19 | 24.93 |
| Total | 3.7514 | 0.003908 | 100.00 | 100.00 |

Table 9 was made by taking the averages of the figures in Table 8. Some of the cities collected two of the divisions together and gave the result under one division; thus, New York collected the street-sweepings and ashes together and gave the total as ashes.

Table 10 was made up by using the foregoing percentages to divide those double collections, and gives the averages for all the cities. It is, therefore, more nearly correct than Table 9.

TABLE 10.

| | Pounds. | Yards. | Percentage. | |
|---|---|---|---|---|
| | | | By weight. | By volume. |
| Garbage | 0.5296 | 0.000460 | 15.27 | 12.13 |
| Street-Sweepings | 0.4992 | 0.000587 | 14.39 | 15.48 |
| Ashes | 2.2290 | 0.001696 | 64.28 | 44.71 |
| Rubbish | 0.2101 | 0.001050 | 6.06 | 27.68 |
| Total | 3.4679 | 0.003793 | 100.00 | 100.00 |

The average collections per capita per day for the cities mentioned are given in Table 9.

The figures given in Table 8, for the monthly collections of general refuse, in pounds per capita per day, are shown graphically in Fig. 1.

In the same manner, Figs. 2 to 4 show graphically the collections of ashes, garbage and rubbish. All these diagrams show a characteristic maximum about January and a minimum about

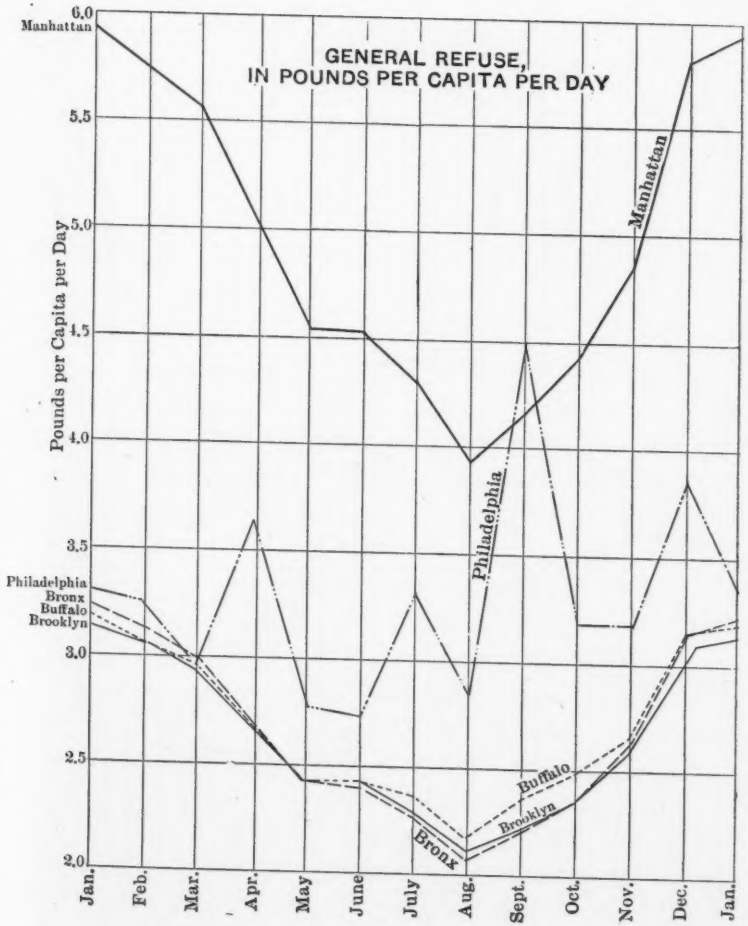

GENERAL REFUSE,
IN POUNDS PER CAPITA PER DAY
Pounds per Capita per Day
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Manhattan
Philadelphia
Bronx
Buffalo
Brooklyn
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.

FIG. 1.

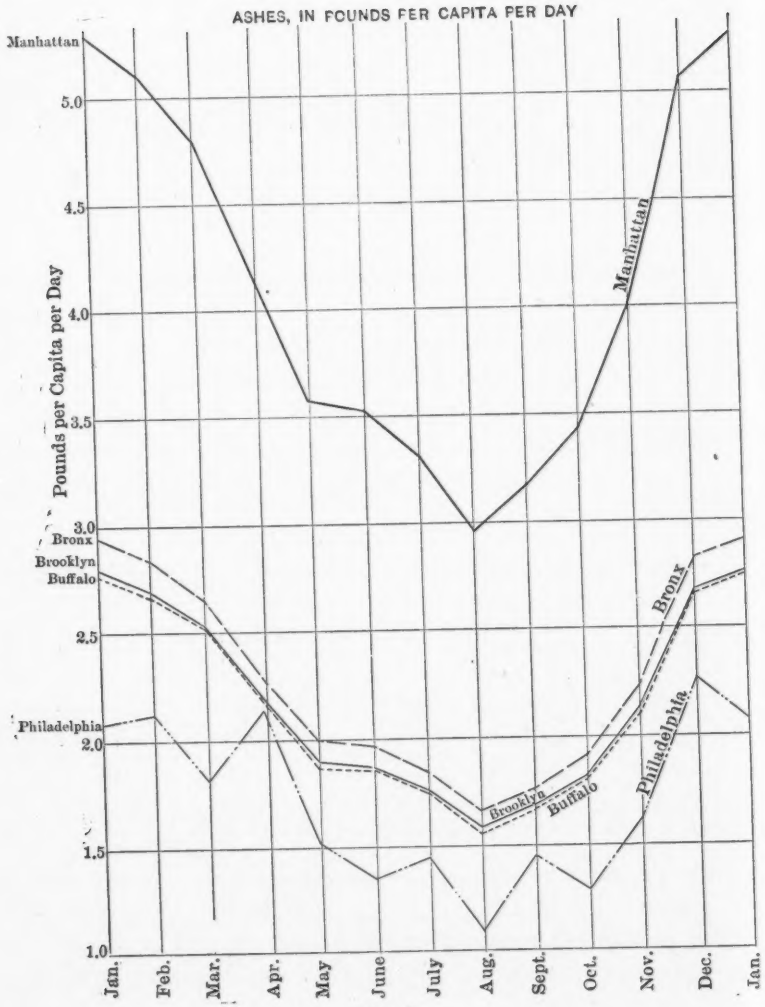

ASHES, IN POUNDS PER CAPITA PER DAY
Pounds per Capita per Day
Manhattan
5.0
4.5
4.0
3.5
3.0
Bronx
Brooklyn
Buffalo
2.5
Philadelphia
2.0
1.5
1.0
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Manhattan
Bronx
Brooklyn
Buffalo
Philadelphia

FIG. 2.

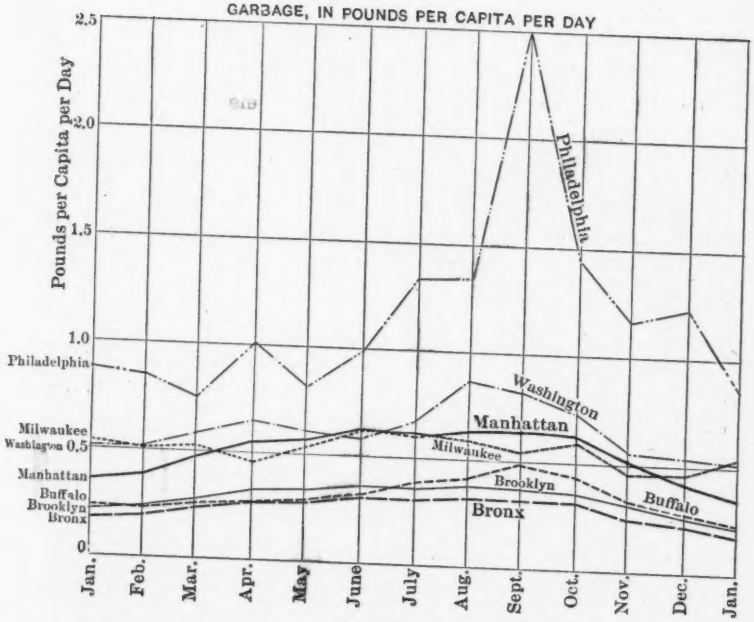

GARBAGE, IN POUNDS PER CAPITA PER DAY
Pounds per Capita per Day
2.5
2.0
1.5
1.0
0.5
0
Philadelphia
Washington
Manhattan
Milwaukee
Brooklyn
Buffalo
Bronx
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.

FIG. 3.

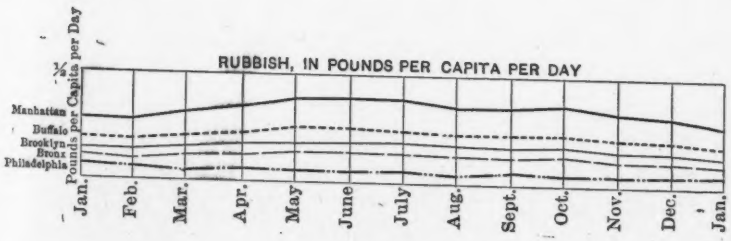

RUBBISH, IN POUNDS PER CAPITA PER DAY
Pounds per Capita per Day
Manhattan
Buffalo
Brooklyn
Bronx
Philadelphia
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.

FIG. 4.

August. The maxima and minima are evidently caused by the collection of ashes, because the rubbish collections, while much more uniform than garbage or ashes, are in maximum during the summer months, and the garbage is in maximum about September.

Fig. 5 shows the monthly collections, in pounds per capita per day, for the Borough of Manhattan, New York City.

In studying these diagrams, it must be borne in mind that the ash collections as reported for the Borough of Manhattan, New York City, also contain the street-sweepings. The curve, therefore, representing Manhattan in Fig. 2 is too high by just the amount of the street-sweepings, which are not reported separately. In the same manner, in Fig. 3, the curve representing garbage collections for Philadelphia is too high, as some rubbish and ashes are collected and reported under the head of garbage.

In Fig. 1, the curve representing Manhattan (as well as the figures in Table 8 for the Borough of Manhattan) is higher than those of the other cities reported, which can be accounted for by the fact that the territory of the Borough of Manhattan is completely built over, and the whole population is served by the collection carts. In the other cities there are outlying districts which are included in the population, but which are not served by the collection carts. It is probable, therefore, that the actual figures for Manhattan are more accurate than for some of the other places.

## The Fuel Value of Refuse.

The value of refuse as a fuel depends on the combustible matter which it contains. There does not appear to be much difference in the general make-up of the combined refuse as collected in America and Europe. It differs more in quantity than in complection.

Garbage will burn, as can be proved by throwing it into a range or stove. It requires enough heat to evaporate the water, and then the dry matter will burn of itself and assist in drying the next charge. This dried portion will generate about 7 500 B. t. u. per lb.

The combustible in the ashes has a total heat of combustion varying from, say, 10 000 to 14 000 B. t. u. per lb. Therefore, the dry ash, on a basis of 25% of combustible, will generate about 3 000 B. t. u. per lb. As the ashes, according to the analyses given

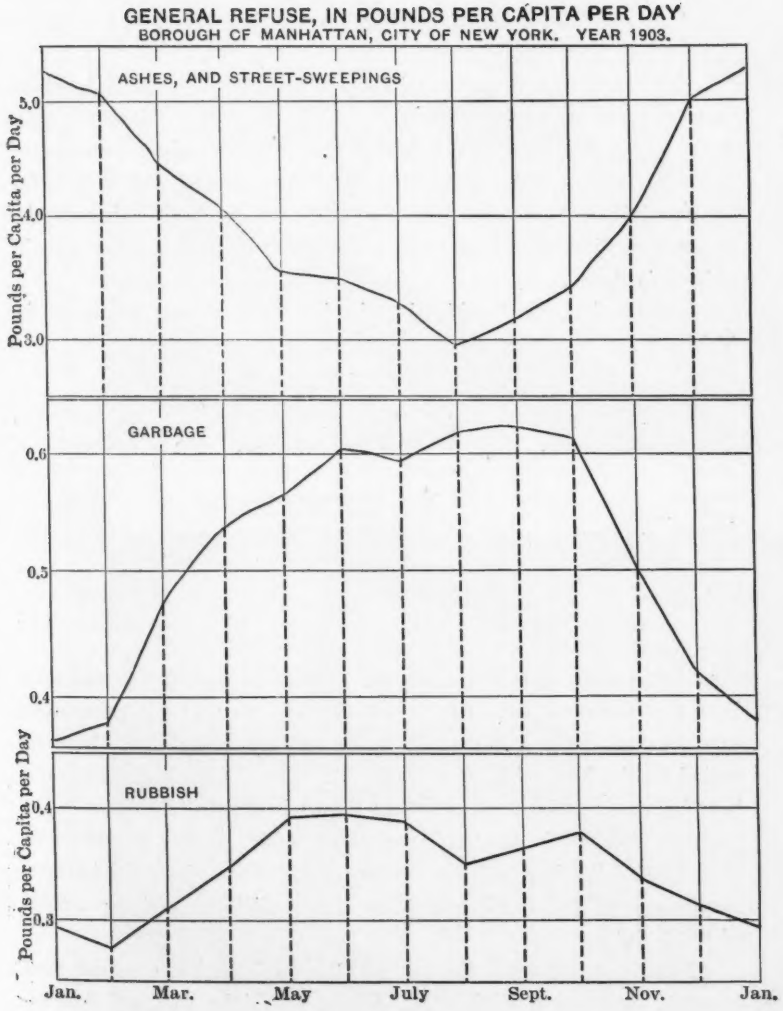

GENERAL REFUSE, IN POUNDS PER CAPITA PER DAY
BOROUGH OF MANHATTAN, CITY OF NEW YORK. YEAR 1903.
ASHES, AND STREET-SWEEPINGS
Pounds per Capita per Day
5.0
4.0
3.0
GARBAGE
0.6
0.5
0.4
RUBBISH
Pounds per Capita per Day
0.4
0.3
Jan.
Mar.
May
July
Sept.
Nov.
Jan.

FIG. 5.

before, contain an average of more than 25% of combustible, there is an allowance at this latter figure for some moisture.

The rubbish, being composed principally of paper, rags and wood, has a total heat of combustion varying from, say, 5 000 to 7 500 B. t. u. per lb.

The street-sweepings contain some combustible material, which can be taken as having a total heat of combustion of about 6 000 B. t. u. per lb. The remainder of the street-sweepings consists of incombustible material and water. If it be assumed that 33% is incombustible, 42% combustible, and 25% water, the burning of the street-sweepings would generate about 2 000 B. t. u. per lb., a probably safe figure.

Assume that the combined collection is composed as shown in Table 11:

TABLE 11.

| Classification. | City collections. | Used as fuel. |
|---|---|---|
| Garbage | 15.0% (70% moisture) | 22.9% |
| Ashes | 64.0% (25% combustible) | 48.7% |
| Rubbish | 7.0% (33⅓% sorted out) | 7.1% |
| Street-sweepings | 14.0% | 21.3% |
| Totals | 100.0% | 100.0% |

Also, assume that 33⅓% of the rubbish is sorted out and only half the ashes are delivered to the furnace, so that the percentage of the constituents as thrown into the furnace would be in the ratio stated in the last column of Table 11. From these assumptions, a heat balance can be worked out as shown in Table 12.

The combustible portion is: garbage, 0.0687; ashes, 0.0913; rubbish, 0.064 (allowing 10% for the incombustible portion); and street-sweepings, 0.071 (allowing 33% as incombustible); making a total of 0.295 lb.

If the heat is passed through a boiler, and the losses be assumed at 40%, then the available useful heat would be $2\,391 \times 0.60 = 1\,434$ B. t. u., or sufficient to evaporate 1.48 lb. of water from and at 212° fahr.

If 1 lb. of coal can evaporate 9 lb. of water, and is worth $3 per

PLATE XXXIV.
PAPERS, AM. SOC. C. E.
APRIL, 1906.
PARSONS ON
REFUSE DISPOSAL.

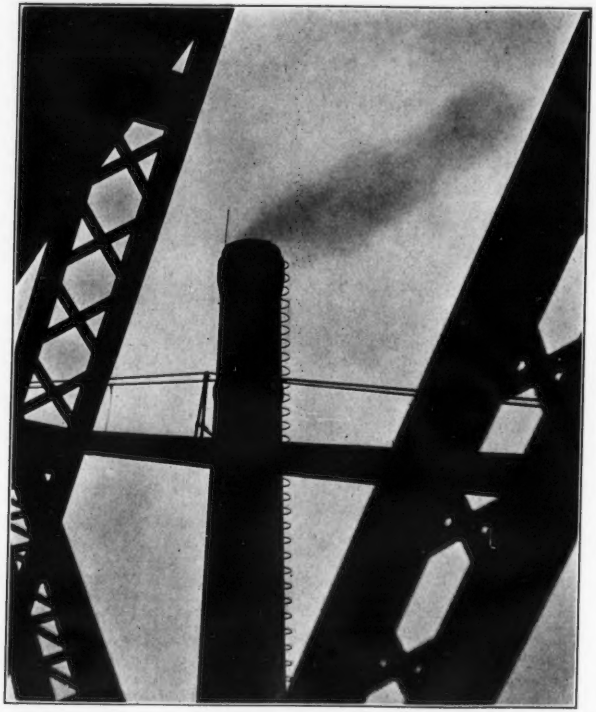


FIG. 1.—SMOKE FROM RUBBISH INCINERATOR, WHEN BURNING DRY RUBBISH.

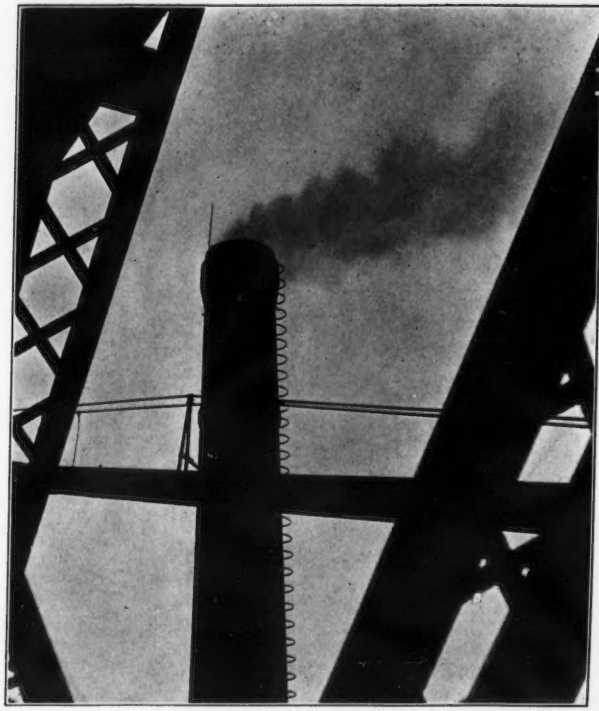


FIG. 2.—SMOKE FROM RUBBISH INCINERATOR, WHEN BURNING WET RUBBISH.



ton, then the value of this refuse as a fuel would be ($1.48 ÷ 9) × 3.00 = $0.49 per ton.

TABLE 12.—ESTIMATE FOR HEAT BALANCE.

Temperature of Air, 60° fahr. Temperature of Furnace, 2 000° fahr. Fuel: City Refuse, Combined Collections—One Pound, moderately dry.

| | | Total heat of combustion. B. t. u. | Dissipation of heat. B. t. u. |
|---|---|---|---|
| Garbage: | Dried portion: 0.229 × 0.30 × 7 500 | 515 | ..... |
| | Moisture; 0.229 × 0.70 × [(212—60) + 966 + 0.48 (2 000 — 212)] | ..... | 317 |
| Ashes: | On the basis that only three-fourths of the combustible is burned; then 0.487 × 0.75 × 3 000 | 1 095 | ..... |
| Rubbish: | On the basis that one-third has been sorted out; then 0.071 × 5 000 | 355 | ..... |
| Street-sweepings: | On the basis that there is 33⅓ incombustible matter; then 0.213 × 2 000 | 426 | ..... |
| Heating fuel mass: | Taking the specific heat of the mass at 0.2; then 1 × 0.2 × (2 000 — 60) = 388, of which, say, one-third is lost through raking out the hot ashes | ..... | 129 |
| Heating air supply: | * On the basis of 4.2 lb. of air per lb. of fuel; then, 4.2 × 0.2375 (2 000 — 60). This is about 14.3 lb. of air per lb. of combustible. | ..... | 1 945 |
| | Estimated British thermal units per pound.... | 2 391 | 2 391 |

* Pounds of air per pound of fuel calculated by difference.

It would be possible to vary the proportions of the constituents fed to the furnace, as long as sufficient combustible material was supplied to evaporate the moisture in the garbage. This condition can be attained by practice at the furnace. It is also self-evident that an increased efficiency will be obtained if the air supplied be heated.

In the same manner, another heat balance can be worked out for the burning of garbage, rubbish and street-sweepings, when all the ashes are kept out of the furnace and utilized for land filling.

Taking the same general analysis as before, for the combined collections, the fuel proportions would be as shown in Table 13.

Assume as before that one-third of the rubbish is sorted out as marketable; then the percentage of the constituents as thrown into the furnace would be in the ratio stated in the last column of Table 13.

TABLE 13.

| Classification. | City collections. | Used as fuel. |
|---|---|---|
| Garbage | 15% (70% moisture) | 44.5% |
| Rubbish | 7% (33⅓% sorted out) | 13.9% |
| Street-sweepings | 14% | 41.6% |
| | | 100.0% |

TABLE 14.—ESTIMATE FOR HEAT BALANCE.

Temperature of Air, 60° fahr. Temperature of Furnace, 2 000° fahr. Fuel: City Refuse—Garbage, Rubbish and Street-Sweepings, One Pound.

| | Total heat of combustion. B. t. u. | Dissipation of heat. B. t. u. |
|---|---|---|
| Garbage: Dried portion; $0.445 \times 0.30 \times 7\,500$ | 1 001 | ..... |
| Moisture; $0.445 \times 0.70 \times [(212 - 60) + 966 + 0.48\,(2\,000 - 212)]$ | ..... | 615 |
| Rubbish: $0.139 \times 5\,000$ | 695 | ..... |
| Street sweepings: $0.416 \times 2\,000$ | 832 | ..... |
| Heating fuel mass: $1 \times 0.2 \times (2\,000 - 60)$, of which about one-third is lost | ..... | 129 |
| Heating air supply: On the basis of 3.9 lb. of air per lb. of fuel; $3.9 \times 0.2375 \times (2\,000 - 60)$. This is about 9.9 lb. of air per lb. of combustible | ..... | 1 784 |
| Estimated British thermal units per pound | 2 528 | 2 528 |

The combustible portion is: garbage, 0.1335; rubbish, 0.1251 (allowing 10% for the incombustible portion); and street-sweepings, 0.1386 (allowing 33% as incombustible); making a total of 0.3972 lb.

If the heat is passed through a boiler, and the losses are assumed at 40%, then the available useful heat would be $2\,528 \times 0.60 = 1\,516$ B. t. u., or sufficient to evaporate 1.57 lb. of water from and at 212° fahr.

On the basis of 34.5 lb. of water evaporated from and at 212° fahr., as equivalent to 1 b. h. p., these two results would represent a boiler horse-power for about 23.3 lb. of combined collections and 22.0 lb. of mixed garbage, rubbish and street-sweepings.



FIG. 1.—FRONT OF EAST FURNACE, SHOWING STOKING DOORS.

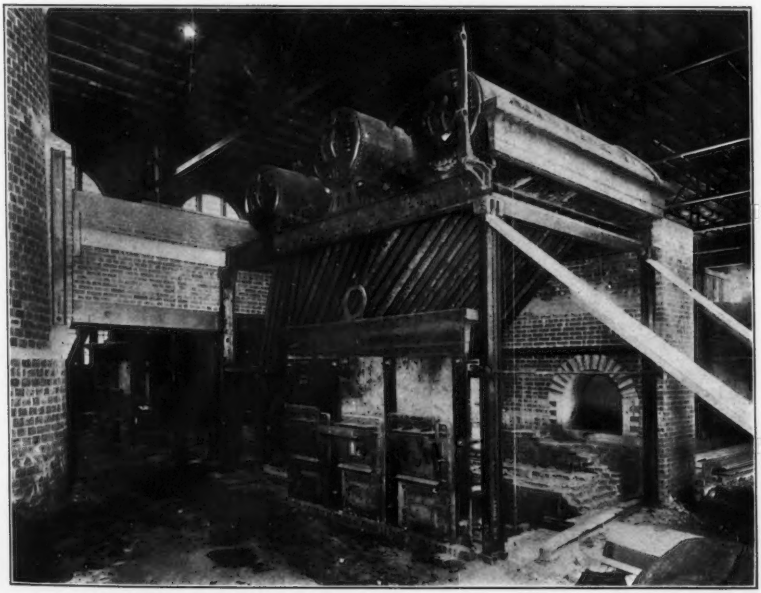


FIG. 2.—BOILERS FOR WILLIAMSBURG BRIDGE LIGHTING STATION AND RUBBISH INCINERATOR PLANT.

The results also indicate that, in order to obtain a high furnace temperature, an artificial draft is needed, so as to get the benefit of a thorough mixture of the oxygen with the fuel and not require too great a surplus of air. In practice, the highest evaporative results per pound of collection burned have been obtained when the boiler is set directly over the fires, as the heat is direct and the losses are reduced to a minimum. Such a plan, however, is not conducive to the maintenance of high temperatures in the furnace, and, consequently, the complete destruction of the mass by thorough combustion is apt to be sacrificed. As the latter consideration is of paramount importance, the boilers should be set to receive the gases of combustion after the combustion has been completed, and while still at high temperature.

The experience obtained in England by the burning of mixed collections shows an evaporation varying from ½ to 2 lb. of water from and at 212° fahr. per lb. of refuse. The best results are obtained by the use of artificial drafts, so as to obtain the benefit of a thorough mixture of the gases with the smallest air supply. The air supplied in the blasts is about 3½ lb.* per lb. of average mixed refuse.

Table 15 gives some figures relative to the total heats of combustion of the constituent elements of refuse.

TABLE 15.—Approximate Calorific Values of Refuse.

| | British thermal units, per pound. | Authority. |
|---|---|---|
| Garbage, dry | 7 500 | H. de B. Parsons.‡ |
| " as collected | 800 | " ‡ |
| Bones and offal, dry | 8 000 | Dawson.† |
| " " average moisture | 5 333 | " |
| Ashes, combustible portion | 12 000 | H. de B. Parsons. |
| " as collected, average | 3 000 | " |
| Rubbish, from | 7 500 | " ‡ |
| to | 5 000 | " ‡ |
| Paper, straw, fibrous matter, and vegetable refuse, dry | 3 800§ | Dawson.† |
| Paper, straw, fibrous matter, and vegetable refuse, average moisture | 2 500§ | " |
| Rags, dry | 5 000 | " |
| " average moisture | 3 333 | " |
| Wood, dry | 7 800 | H. de B. Parsons. |
| " average moisture | 6 500 | " |

* George Watson. *Transactions*, Am. Soc. M. E., Vol. XXV, 1904.

† "Disposal of Municipal Refuse," *Transactions*, Am. Soc. C. E., Vol. LIV, Par t 1905.

‡ Estimated from its composition, and verified by its behavior in the incinerators.

§ The writer considers this too small.

## The Rubbish Incinerator.

In New York the city refuse is separated into classes and collected by different carts. The rubbish collections include paper of all kinds, books, magazines, cardboard, rags, barrels, boxes, crates, shoes, hats, pieces of leather, rubber, cans, metals, garments, beds, bedding, mattresses, bed springs, sofas, chairs, broken furniture of all kinds, and various other articles, both large and small, of almost every conceivable nature. The material is heterogeneous and bulky. As packed in the collection carts, its weight averages 141 lb. per cu. yd., which is the average of the actual weighing of 135 carts from different districts.

As this material makes a very poor land-fill, and as it cannot be dumped at sea without danger of its floating back on the beaches, the rubbish incinerator plant was designed by the writer for the Department of Street Cleaning, in order to reduce its bulk, to transform it into ash which can be used for land-fill, to provide better picking facilities than is afforded by dumping directly into scows, Fig. 1, Plate XXX, and to destroy in a sanitary manner the beds, bedding, mattresses and furniture, some of which may be carriers of disease.

*Location.*—The plant is located on city property, beneath the Williamsburg Bridge, facing Delancey Slip, between East Street and Tompkins Street, Borough of Manhattan. It is thus close to the East River, being separated therefrom only by the width of East Street.

*General Arrangement.*—The arrangement of the plant is shown on Plate XXXI. The collection carts drive into the building through any of the four doors on the Delancey Slip front, and dump their loads on the belt conveyor. If the material arrives faster than it is wanted on the conveyor, the loads are dumped on the floor of the receiving room, the material then being pushed upon the conveyor by hand labor as desired. The empty carts go back for more material.

The conveyor carries the material between two rows of "trimmers," as the men are called who pick out the marketable material and place the different kinds in separate boxes. This marketable material is baled by presses and by hand, and removed by the contractor who pays the city for the privilege.

The material not picked passes to the end of the conveyor, where it is dumped on a steel charging floor, and pushed into the furnaces by furnace men.

The street-sweeping carts drive up an inclined runway and dump directly on the charging floor, thus preventing the street dirt from injuring the salable portion of the rubbish.

The furnaces are connected with a stack, and, by means of dampers, the hot gases may be diverted either directly to the stack or through the boilers.

On one side of the building doors are provided for carts to enter to remove the ashes and the baled material without interfering with the material being received.

A second floor over part of the building provides storage space for the material to be burned on holidays when there is no collection, and for night use. The receiving floor also provides additional space for storage, as well as the yards on both sides of the building, and a scow, filled at some other dumping station, is, furthermore, kept at the wharf opposite the building. In this way there is no trouble from lack of material to burn.

*Building.*—The building is 150 ft. deep and 70 ft. wide. The ground floor is at the level of the sidewalk, and is paved with Belgian blocks. Over the northern half and along the west side there is a second floor. This upper floor, used for storage, is reached by an inclined driveway outside the structure.

The front of the building, Fig. 2, Plate XXX, is of brick, with buff brick facing, and the sides are of Phœnix, hollow, tile-block construction, stuccoed on the outside. The pilasters beneath the roof trusses are of red brick, locked into the tile blocks, course and course.

The roof is supported by steel trusses and purlins, and is covered with saturated roofing felt, coal-tar pitch and gravel. The upper floor is of reinforced concrete on steel beams and girders, supported on steel pipe columns.

The windows are as large as could conveniently be made, consistent with strength in the walls.

A division wall of tile blocks, carried to the upper floor, divides the receiving space from the furnace space, and keeps the combustible material away from the fires. This wall does not reach en-

tirely across the building, and the space is used as a driveway for ash carts, which can enter at one of the side doors and pass out at the other.

*Conveyor.*—The conveyor is of the metallic, apron type, 48 in. wide, with side angles to hold the rubbish. The flights are each 6 in. long and the full width of the conveyor, and are lapped over each other, so that there is no space between them as they travel over the head shafts. Fig. 1, Plate XXXII, shows the conveyor as it rises from the receiving floor to the tops of the furnaces, and passes between the sorting boxes.

By spreading out the material on the conveyor the opportunity for picking is greatly facilitated. The picking and sorting privilege is let to a contractor, who pays a sum sufficient to cover more than all the labor charges in the plant. The amount of material picked out varies with the market value for the old paper, cans, etc., between 25 and 40% by weight of the material delivered. Some of this material, baled and ready for removal, is shown in Fig. 3, Plate XXX.

To facilitate the unloading of scows, which bring rubbish from other city districts, a conveyor across East Street has been designed, but not yet constructed, Plate XXXIII. This will unload the material on the upper floor, from which it will be pushed through a chute to the main conveyor.

Both these conveyors are arranged for power drives, using steam from the boilers. The speed of the conveyor is controllable, but the working speed is about 50 ft. per min.

*Charging Platform.*—The platform over the furnaces is of steel construction, covered with steel floor-plates. The conveyor dumps upon this platform, Fig. 2, Plate XXXII.

*Furnaces.*—There are two furnaces, of somewhat different design. The west furnace was designed by F. L. Stearns, Assoc. M. Am. Soc. C. E., and has two grates for part of its length. The area of the upper grate is 113 sq. ft. The east furnace was designed by the writer, and has one grate, 74 sq. ft. in area, divided into two cells by a division wall, as shown in Fig. 6. The material is fed through two chutes at the back, is stoked forward on the grate as wanted, and the clinkers are pulled out through the stoking doors, Fig. 7. The motion of the material is thus continuous. This sys-

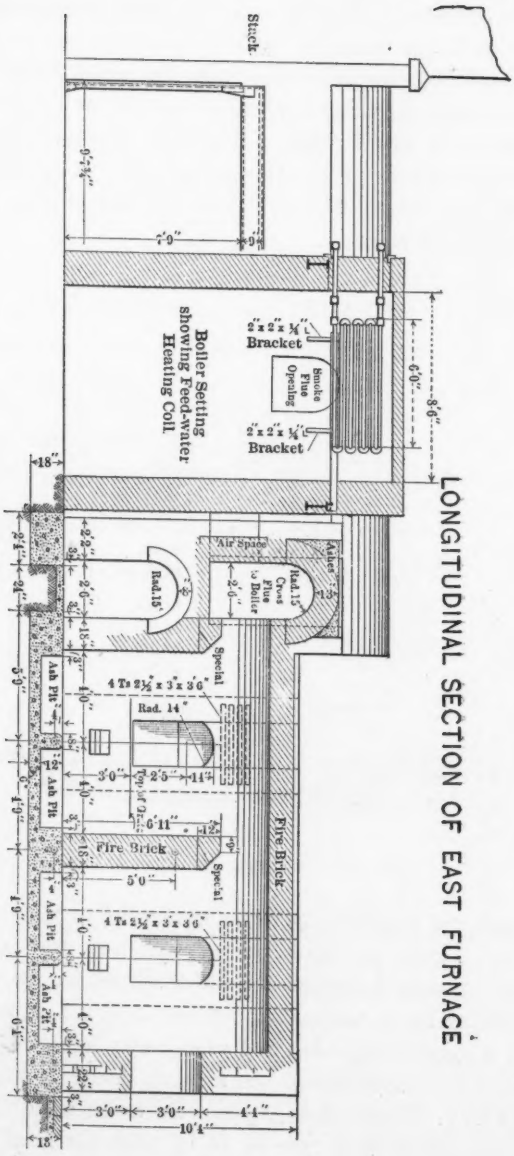

Stack
Boiler Setting showing Feed-water Heating Coil
Bracket
Bracket
Smoke Flue Opening
Air Space
Ashes
Rad. 15"
Rad. 14"
Special
Fire Brick
Ash Pit
LONGITUDINAL SECTION OF EAST FURNACE

FIG. 6.

tem has worked well, with the exception of the damage to the fire-brick lining due to the stoking tools, and improvements are planned to remedy this trouble.

Both furnaces are of brick, with fire-brick lining, and are strongly tied with stays made of 8-in. channels set in pairs.

The hot gases pass through a cross-flue, with dampers, either to the boilers or to the stack. The dampers are of special tile, and necessarily very large, Fig. 8. They are raised and lowered by triplex blocks and chains.

CROSS-SECTION OF EAST FURNACE

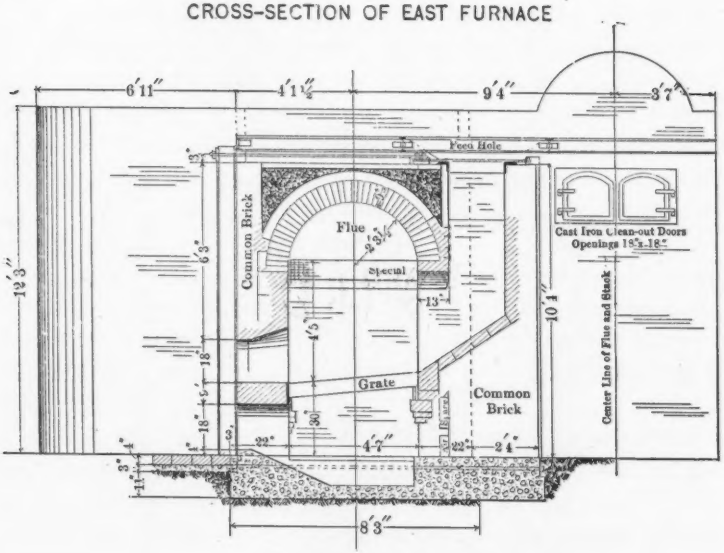
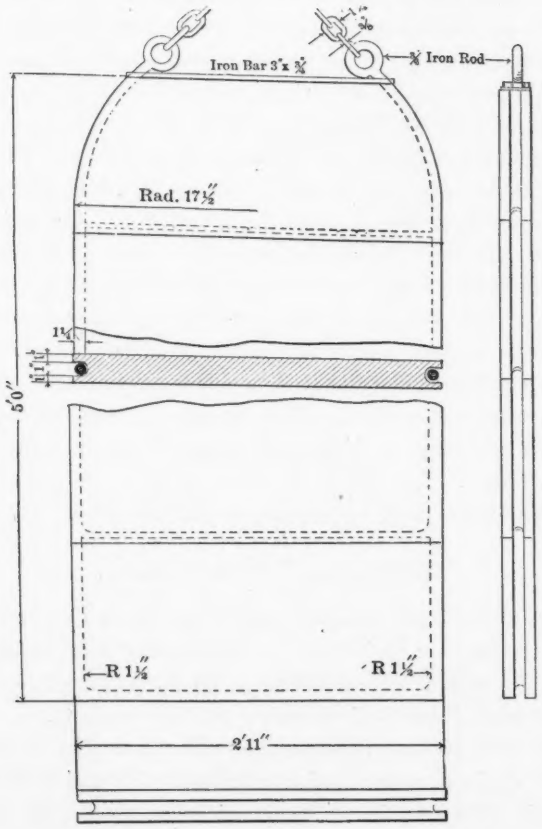



FIG. 7.

The material burns freely, often consuming at the rate of 40 lb. per sq. ft. of grate per hour. Even when wet, that is, rainy day collections, or when wet street-sweepings are fed in, the effect is not detrimental to rapid combustion. When dry, the smoke from the stack has a light bluish color, and when wet a light yellowish tinge. Rarely does the smoke exceed the amount shown in Figs. 1 and 2, Plate XXXIV. These photographs were taken when the furnaces were burning about 35 lb. per sq. ft. of grate per hour, the former when the rubbish was dry and the latter when it was wet.

On the end of each furnace there is a large door, to feed in beds, furniture and similar bulky articles. Fig. 1, Plate XXXV, shows the stoking doors on the front of the east furnace.

*Boilers.*—The boilers are Stirling water tubular, Fig. 2, Plate




TILE DAMPER USED IN FLUE

Fig. 8.

XXXV, and each contains 1 890 sq. ft. of effective heating surface. The tubes are 3¼ in. in diameter. Each boiler has its regular coal grate, and as the hot gases from the rubbish furnaces enter above these grates, they are always ready for coal firing (by simply arrang-

ing the dampers), should any accident happen to the fuel supply. The coal firing doors are placed on one side of the boiler setting, instead of at the end, as usual, a change made to accommodate the arrangement of the plant.

Each boiler has a feed-water economizer coil of brass pipe, set in the flue to the stack. These coils are connected with unions and can be withdrawn at any time without stopping the plant.

*Stack.*—The stack is of hollow, radial-block construction, built by M. W. Kellogg and Company. It is 200 ft. high, so that the top would be 75 ft. above the roadway of the bridge. The outside diameter at the base is 17 ft. and at the top 5 ft. 9 in. The stack is lined to a height of 135 ft. above the foundation. The lining above the smoke inlet is of unusual construction, being in the form of a continuous helical band, 16 ft. 5 in. high at any point. It is supported on corbels, but, being arranged helically, there are only three corbel blocks in each horizontal row of the outer column. The object of this helical arrangement is to prevent the outer column from cracking, when exposed to sudden changes in temperature, due to continuous corbeling in horizontal courses. This arrangement is shown in Fig. 9.

The foundation is of concrete, supported on piles.

### The Electric Lighting Station.

*Building.*—In order to utilize the steam generated, an electric lighting station was built by the Department of Bridges, from plans by the writer. The building is 60 ft. deep and 50 ft. wide, and is separated from the incinerator building by 20 ft.

It is of steel skeleton construction, with the trusses supporting a reinforced cinder-concrete roof, covered with felt and coal-tar pitch and gravel. The curtain walls are of brick, with large windows, and are made to match the other building.

The north half of the building has a second floor of reinforced cinder-concrete construction, designed to be used at some future time for a storage battery plant. The general arrangement is shown in Plates XXXI and XXXVI.

*Machinery.*—There are two 100-k.w. and one 50-k.w. direct-connected units. The generators are multipolar, direct-current ma-

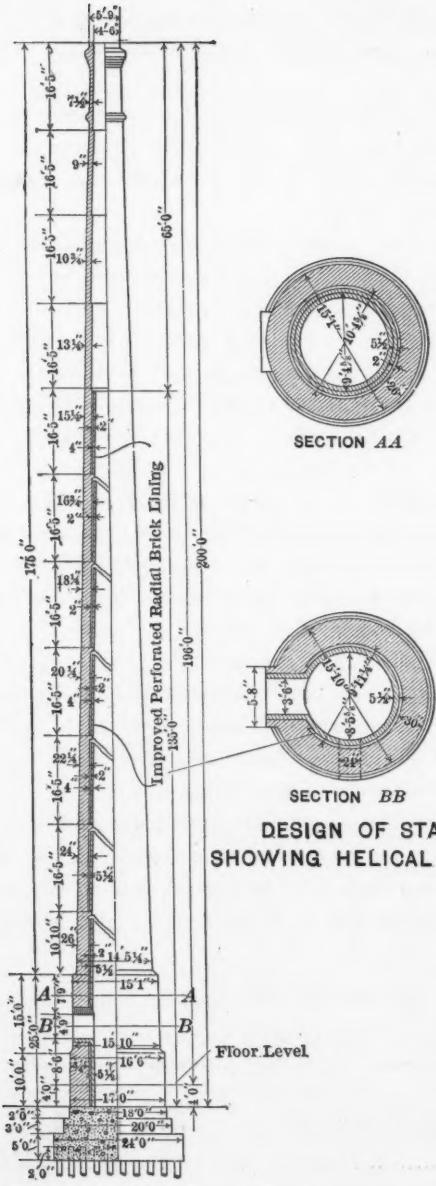

Improved Perforated Radial Brick Lining
Floor Level
SECTION AA
SECTION BB
DESIGN OF STACK,
SHOWING HELICAL LINING.

FIG. 9.

chines, built by the Burke Electric Company, and arranged for the three-wire system. They are all wound for 250 volts, with 125 volts on either side.

The generators are driven by "Ideal," cross-compound, horizontal, condensing engines, the large units having cylinders 12 and 20 in. in diameter with 12-in. stroke, and the small unit 9 and 16 in. in diameter with 10-in. stroke.

Each unit has an independent Blake, vertical beam, jet condenser, for which the suction and discharge are connected to the East River. The exhausts are all by-passed, and extend through the roof, so that the engines can be operated as non-condensing.

The exhausts from the condensers and feed pumps are passed into an open feed-water heater of the "Cockrane" type, into which are also returned the discharges from all traps that do not handle oil or grease.

*Piping.*—The piping is as simple as possible. The steam main is 7 in. in diameter, graded down from the boilers, with the far end turned down to form a pocket for drainage of condensation, and trapped. The supply branches are all taken from the top, and expansion is provided for by easy bends.

*Current.*—The electricity generated is used to light the Williamsburg Bridge, the incinerator building and the lighting station.

The cables are in underground conduits to the foot of the intermediate tower of the bridge, whence they are carried up the tower to the electric distribution of the bridge.

The number of lights, etc., at present connected, is given in Table 16, but when the storage plant is completed, the electric station can have a day load, and the current thus stored can be used for additional work as well as to assist the bridge load in cases of accident.

TABLE 16.—LIGHTS, ETC., SUPPLIED BY LIGHTING STATION.

| Lights, etc. | Bridge. | Incinerator. | Station. |
|---|---|---|---|
| 2 000-c. p. arc lamps | 168 | 8 | 4 |
| 16-c. p. incandescent lamps | 707 | 40 | 20 |
| Electric heaters | 20 | ..... | ..... |
| Electric motors | 3 | ..... | ..... |

The plant was formally opened by Mayor McClellan on October 30th, 1905. The cost of the plant was as follows:

| | |
|---|---|
| Incinerator, including building, stack, east furnace, and equipment | $26 768 |
| West furnace | 4 000 |
| Runway | 1 550 |
| Conveyor | 1 875 |
| Lighting station, including building, all machinery, boilers, and electrical equipment. | 49 391 |
| Total cost | $83 584 |

On December 20th and 21st, 1905, the writer conducted evaporative tests, the data and result of which are given in Table 17. Each boiler, with its furnace, was tested separately, under similar conditions.

Figs. 1 and 2, Plate XXXIV, show the average condition of the smoke during the tests.

Fig. 10 shows an average steam card produced on a night run.

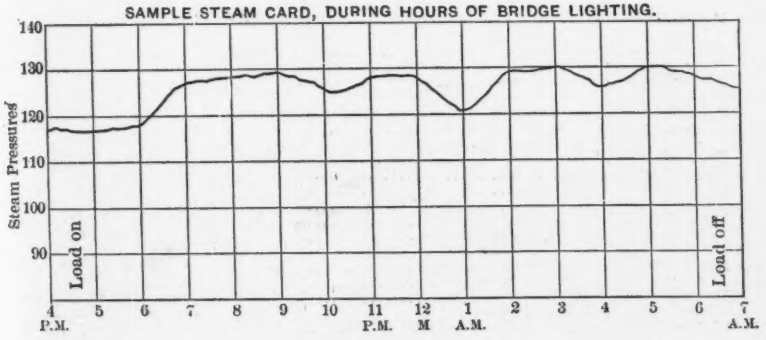



FIG. 10.

During the ordinary weekday, the quantity of rubbish consumed is about 160 loads, equivalent to 22 560 lb.

TABLE 17.—Data and Results of Evaporative Tests; Rubbish Incinerator and Electric Lighting Station, Delancey Slip, Borough of Manhattan, New York.

Trials made by H. de B. Parsons.

Kind of fuel, city rubbish collections.

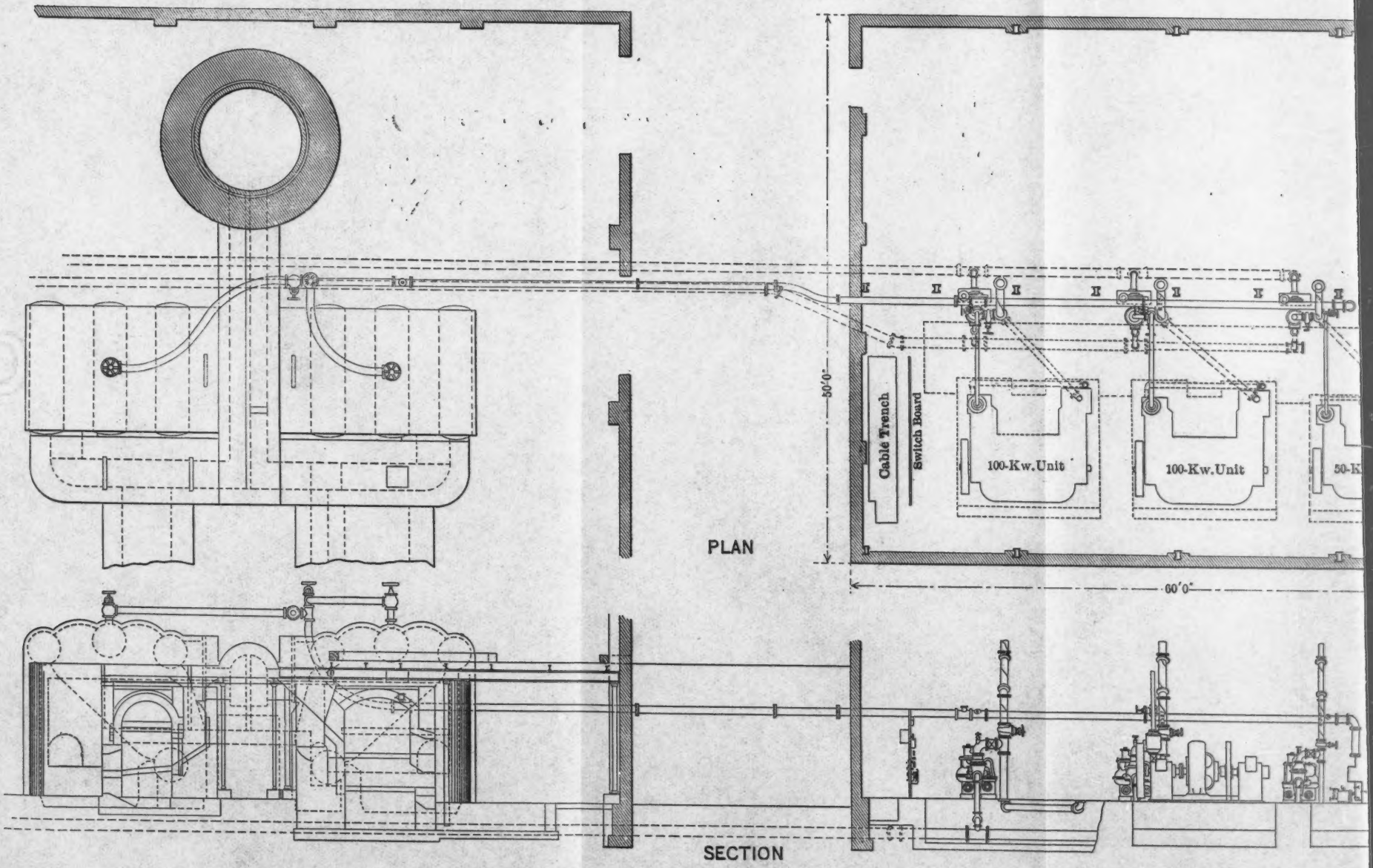
Method of starting and stopping, alternate.

Make of boilers, Stirling Water Tubular.

| Data. | West boiler. | | East boiler. | |
|---|---|---|---|---|
| Grate surface of furnace | | 113 sq. ft. | | 74 sq. ft. |
| Effective water-heating surface | | 1 890 " " | | 1 890 " " |
| Surface of feed-water heater coil in flue | | 60 " " | | 60 " " |
| TOTAL QUANTITIES. | | | | |
| Date of trial | | Dec. 20th, '05. | | Dec. 21st, '05. |
| Duration of trial | | 5.5 hours. | | 5.5 hours. |
| Weather | | Fair. | | Rainy. |
| Condition of rubbish | | Dry. | | Wet. |
| Weight of rubbish delivered | | 31 193 lb. | | 21 175 lb. |
| Weight of rubbish picked out as: | | | | |
| marketable | | 8 926 " | | 7 245 " |
| paper | 6 876 | | 6 435 | |
| rags | 1 800 | | 610 | |
| cans | 250 | | 200 | |
| Weight of rubbish burned | | 22 267 " | | 13 930 " |
| Weight of ash, estimated | | 10% | | 10% |
| Total weight of water fed to boiler | | 29 925 " | | 24 675 " |
| Equivalent water evaporated, from and at 212° | | 36 568 " | | 30 054 " |
| Number of furnace men: | | | | |
| stokers | 6 | | 2 | |
| feeders | 3 | | 2 | |
| Equivalent evaporation per man per ton | | 365 " | | 1 078 " |
| HOURLY QUANTITIES. | | | | |
| Rubbish consumed per hour | | 4 048.5 " | | 2 532.7 " |
| " " " " per square foot of grate. | | 35.8 " | | 34.2 " |
| Water evaporated per hour | | 5 440.9 " | | 4 486.2 " |
| Equivalent evaporation per hour, from and at 212° | | 6 648.7 " | | 5 464.2 " |
| Equivalent evaporation per hour, from and at 212°, per square foot of heating surface | | 3.51 " | | 2.89 " |
| AVERAGES. | | | | |
| Temperature of external air | | 46° fahr. | | 49° fahr. |
| Barometer, inches | | 30.32 | | 29.64 |
| Steam pressure by gauge | | 117 lb. | | 100 lb. |
| Temperature of feed-water | | 40° fahr. | | 40° fahr. |
| Temperature of gases entering boiler | | | | 1 740° " |
| " " " under " | | 1 525° fahr. | | 1 400° " |
| " " " escaping from boiler | | 466° " | | 412° " |
| Force of draft, under boiler, inches | | 0.75 | | 0.55 |
| " " " in flue to stack, inches | | 1.30 | | 1.15 |
| Boiler horse-power developed | | 192.7 | | 158.4 |
| ECONOMIC RESULTS. | | | | |
| Water evaporated, actual, per pound of rubbish | | 1.34 lb. | | 1.77 lb. |
| Equivalent evaporated per pound of rubbish | | 1.64 " | | 2.16 " |

The cost of operating the plant by the City, showing the debits and credits, is given in the financial statement, Table 18. Prior to the construction of the plant, the material was loaded on scows and taken to land-fills. (Previous to the administration of Commis-

PLAN AND SECTION THROUGH ELECTRIC LIGHTING STATION.



CTION THROUGH ELECTRIC LIGHTING STATION.

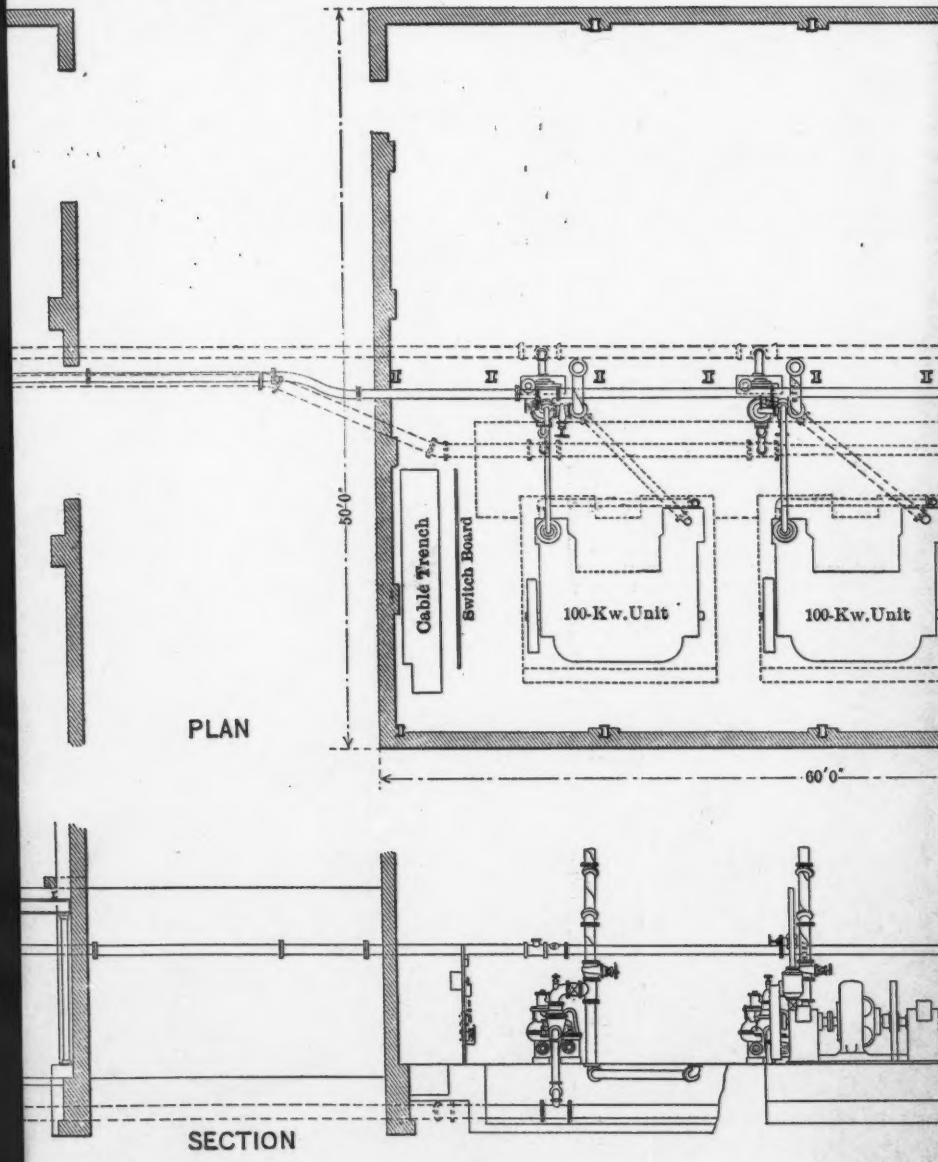
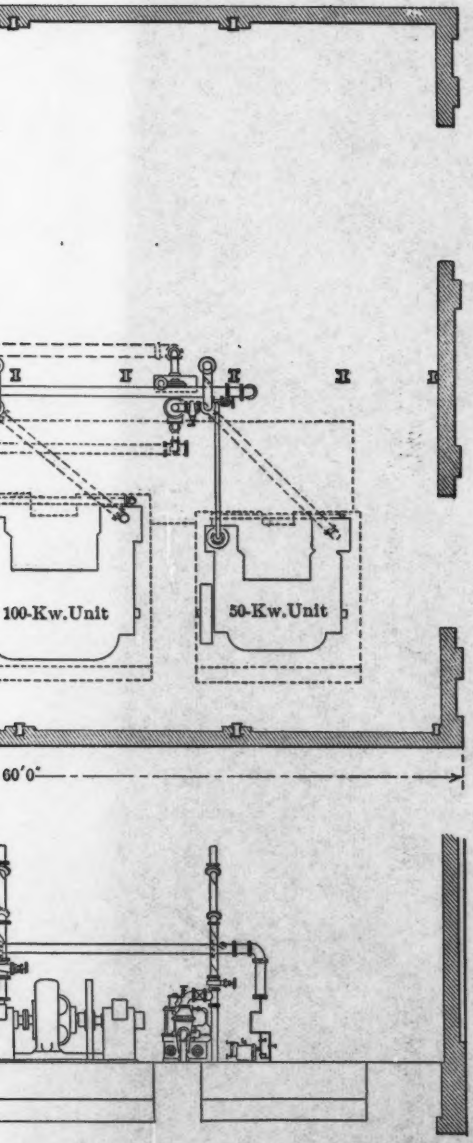


PLATE XXXVI.
PAPERS, AM. SOC. C. E.
APRIL, 1906.
PARSONS ON
REFUSE DISPOSAL.



sioner Woodbury, much of this material was dumped at sea.) These scow loads contained the collections of ashes, street-sweepings and rubbish. The rubbish, therefore, was reduced in bulk, both by compression and by the ashes filling in the voids.

The cost to the City, for towing, unloading and scow hire, averaged, in 1905, $0.1569 per cu. yd. of mixed material. From a study of the records kept by the City, the reduction of the rubbish as collected and delivered occupies three-tenths of its original volume when loaded on the scows.

An average day's work at the plant represents about 1 050 cu. yd. of rubbish delivered during 24 hours.

TABLE 18.—FINANCIAL STATEMENT.

ONE DAY'S WORK. DELANCEY SLIP PLANT.

| | | |
|---|---|---|
| Cost of disposal of rubbish on land-fills. | | |
| 1 050 cu. yd. delivered, compressed on scows, after trimming, to 315 cu. yd. | | |
| 315 cu. yd. at $0.1569 | | $49.42 |
| **Cost, Incinerator.** | | |
| Labor | .... | |
| Ash removal, 7.6 cu. yd. at $0.1569 | $1.20 | |
| Supplies and repairs | 8.00 | |
| Interest, 3½% on $34 193 | 3.28 | |
| | | 12.48 |
| Saving per day | | $36.94 |
| Saving per year, $13 483, or 39.4% on cost. | | |
| **Cost, Electric Lighting Station.** | | |
| Cost of buying electricity | | $80.00 |
| Labor | $20.00 | |
| Supplies, repairs and sundries | 8.00 | |
| Interest, 3½% on $49 391 | 4.74 | |
| | | 32.74 |
| Saving per day | | $47.26 |
| Saving per year, $17 250, or 35% on cost. | | |

The total saving, as shown by Table 18, on the combined plant is $30 733 per annum, or 36.7% on the cost.

There is included in Table 18 no cost for labor charges in the incinerator plant, because the privilege of picking out the marketable rubbish on the belt conveyor is under contract, and the contractor pays to the City a sum which slightly exceeds the expenses of labor in the incinerator building, including the operation of the boilers. Taxes are not included, because the plant is built on City property, purchased to protect the bridge structure overhead.

Prior to the erection of the Delancey Slip plant, the Department of Street Cleaning made tests on the burning of rubbish in a building on North Moore Street and at the rubbish incinerating plant erected at the foot of West Fourth Street, with the results given in Table 19. These experiments were carried on during 1903 and 1904. At the North Moore Street plant a second-hand return-tubular boiler was used, with a grate and setting arranged to accommodate the rubbish.

TABLE 19.

| | North Moore St. | Forty-seventh Street Incinerator. | |
|---|---|---|---|
| Duration of trial, hours | 6 | 2 | 3 |
| Grate surface, square feet | ..... | 90 | 90 |
| Boiler heating surface, square feet | 324 | 2 760 | 2 760 |
| Rubbish burned, pounds | 3 324 | 9 316 | 10 054 |
| Temperature of feed water, degrees, fahr. | 56° | 50° | 50° |
| Steam pressure, pounds | 10 | 80 | 80 |
| Water evaporated, pounds | 3 968.75 | 11 101.00 | ..... |
| Equivalent evaporation, from and at 212° fahr., pounds | 4 648 | 13 365 | 15 139 |
| Equivalent evaporation, from and at 212° fahr., pounds per pound of rubbish | 1.40 | 1.43 | 1.50 |
| Temperature of furnace, degrees, fahr. | 1 500° | ..... | ..... |
| Ashes removed, pounds | ..... | 907 | ..... |
| British thermal units required for evaporation of water from and at 212° fahr., per pound of rubbish | 1 352.4 | 1 381.4 | 1 449.0 |

The ashes produced at the Forty-seventh Street and at the Delancey Slip rubbish incinerating plants were analyzed by the Lederle Laboratories, with the following results:

Sample of Ashes from West Forty-seventh Street Incinerator:

| | |
|---|---|
| Moisture | 2.12% |
| Potassium carbonate | 2.65% |
| Calcium phosphate | 1.98% |
| Alkaline earth carbonates, silicates, soda, oxides of iron and alumina, etc. | 68.05% |
| Organic and volatile matter (loss on ignition) | 25.20% |
| | 100.00% |

Sample of Ashes from Delancey Slip Incinerator:

| | |
|---|---|
| Moisture | 0.75% |
| Nails and other metal | 5.48% |
| Broken glass | 4.05% |
| Bone phosphate | 2.71% |
| Potash | 0.46% |
| Alkaline earth carbonates, silicates, soda, oxides of iron and alumina, etc. | 60.91% |
| Organic and volatile matter (loss on ignition) | 25.64% |
| | 100.00% |

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## CONCERNING THE INVESTIGATION OF OVERLOADED BRIDGES.

By Wilbur J. Watson, M. Am. Soc. C. E.
To be Presented September 5th, 1906.

For some years a large part of the writer's professional work has been the investigation of existing bridges which are subjected to loads greater than those for which they were originally designed; and, in the course of this work, he has found, among bridge engineers, such a divergence of views regarding the maximum unit stresses, etc., which may be safely allowed in an existing structure, that he takes this opportunity of bringing the matter before the Society for discussion, in the hope that thereby greater uniformity of opinion may be established. The rapid development of electric traction lines, both urban and interurban, many of which are built upon highways, has had the effect of overloading many highway bridges.

The writer has in mind an interurban line which was built upon a highway and crossed many bridges. The engineer in charge, who was not a bridge engineer, reviewed the stresses caused by the new loading, and condemned every structure in which they exceeded those recommended by a certain standard specification for highway

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

bridges. On the other hand, lines have been built over old highway bridges without any investigation whatever being made as to the strength of the bridges. It is hardly necessary to state that such lines were built by promoters, without the aid of competent engineers.

One promoter, desiring to show his contempt for engineers in general, told the writer that he had built an interurban line, ten miles in length, and that his total expense for engineering services amounted to $75. The writer having ridden over this line, sees no reason to doubt the promoter's statement.

It is the writer's practice, when called upon to report concerning the safety of an existing structure, to make a careful examination of the structure in the field, in order to determine the following points:

*First.*—The general dimensions;

*Second.*—The sizes of the members, connections, etc., making full allowance for corrosion, if any;

*Third.*—The character of the material, whether steel or iron;

*Fourth.*—The workmanship;

*Fifth.*—The presence of, or liability to, secondary stresses.

The stresses are then computed, and to the dead-load and live-load stresses an amount is added to cover those due to impact, vibration and similar secondary stresses. In computing this allowance for secondary stresses, the rational impact formula, $I = L \frac{L}{L + D}$, is used, in which $I$ equals the allowance to be made for secondary stresses, $L$, the stress due to the live load considered as a static load, and $D$, the stress due to the dead load only. In case there exist secondary stresses due to eccentric connections, which are very common in old highway bridges, or due to other defects in design or execution, these should be added to obtain the maximum.

In regard to allowable unit stresses, it may be stated, as a general principle, that the greatest possible stress in any member should not exceed the elastic limit of the material.

There are two reasons why this limit has been used:

*First.*—In exceeding the elastic limit, the stress causes a permanent distortion of the member, which, in turn, causes a change in the conditions which were assumed in computing the stresses.

*Second.*—The classical experiments of Wöhler and Bauschinger

demonstrated that repeated strains greater than the elastic limit of the material, but much less than the ultimate strength, might cause rupture.*

It is well known that eye-bars and built-up members do not develop the full strength indicated by their sections and by tests on small-sized pieces, and it would appear that it is not safe to assume the elastic limit of full-sized members to be more than about 75% of the elastic limit indicated by tests on small test pieces of the material of which these members are composed. It has also been demonstrated that single angles, connected by one leg only, cannot be depended upon to develop more than about 60% of their computed strength.†

The second cardinal principle, then, as used by the writer, may be stated as follows: The greatest computed unit stress in any member in tension, making full allowance for ordinary and extraordinary secondary stresses, should never exceed 75% of the elastic limit of the material for members symmetrically connected, nor 60% of the elastic limit of the material for angles connected by one leg only. The latter case is very often found in old lattice trusses. This would give, for symmetrically connected members in tension, working stresses of, approximately, 20 000 lb. per sq. in. for iron, 24 000 lb. per sq. in. for soft steel, and 26 000 lb. per sq. in. for medium steel.

In examining old bridges, it is necessary to note carefully the construction of the compression members, as they are often insufficiently stiffened, especially the T-sections formerly used to such an extent. The writer will risk the statement, drawn entirely from personal knowledge, that more failures occur in compression members than in tension members, and he has in mind the failure of an electric railway bridge by the buckling of the top chord (a T-section) under a unit stress in the steel not exceeding 22 000 lb. per sq. in. Full allowance for impact, etc., as outlined above, had been made, and the failure was entirely due to the lack of proper stiffening of the member.

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* Paper by H. B. Seaman, M. Am. Soc C. E., on "The Launhardt Formula, and Railroad Bridge Specifications," and discussion thereon by C. C. Schneider, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. XLI, pp. 140 and 173.

† Paper by J. E. Greiner, M. Am. Soc. C. E., on "Tests of Bridge Members," *Transactions*, Am. Soc. C. E., Vol. XXXVIII, p. 41.

## TABLE 1.—Stresses in Stringers and Floor-Beams of Railway Bridges.

Full allowance has been made for impact, etc., by the use of the impact formula, $I = L \frac{L}{L + D}$.

All these stresses were obtained from the wheel-loads actually used.

| No. | Railroad. | Member. | No. of members. | Flange unit stress. | Maximum rivet-bearing on web. | Material. | Examined in: | Replaced in: | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Railroad..... .... | Stringers..... | ..... | 18 300 | 45 000 | Iron. | 1901 | ..... | In use, 1905. |
| 2* | ..... | " ..... | 32 | 10 200 | 39 000 | " | " | ..... | " " |
| 3* | ..... | " ..... | 4 | 9 500 | 52 400 | " | " | ..... | " " |
| 4 | ..... | " ..... | 8 | 19 100 | 49 100 | " | " | ..... | " " |
| 5 | ..... | " ..... | ..... | 15 500 | 38 000 | Steel. | 1900 | 1903–04 | |
| 6 | ..... | " ..... | ..... | 27 900 | 31 000 | " | " | " | |
| 7 | ..... | Deck-span ..... | ..... | 16 700 | 28 800 | Iron. | " | " | |
| 8 | ..... | " ..... | ..... | 21 400 | 35 600 | " | " | " | |
| 9 | ..... | " ..... | ..... | 23 500 | 37 000 | " | " | " | |
| 10 | ..... | Floor-beams..... | ..... | 16 000 | 38 000 | " | " | " | |
| 11 | Traction Co..... | " ..... | ..... | 22 300 | 33 100 | Steel. | 1903 | ..... | In use, 1905. |
| 12 | " ..... | " ..... | ..... | 23 050 | 38 300 | " | " | ..... | " " |
| 13 | Railroad..... | Stringers..... | ..... | 18 700 | 37 700 | Iron. | 1902 | ..... | Not known, if in use now. |
| 14 | " ..... | " ..... | ..... | 25 600 | 45 800 | " | " | ..... | " |
| 15 | " ..... | Floor-beams..... | ..... | 20 600 | 43 000 | " | " | ..... | " |
| 16 | " ..... | Stringers..... | 12 | 23 200 | 42 400 | Steel. | 1900 | 1904–05 | |
| 17 | " ..... | Floor-beams..... | 5 | 21 000 | 35 700 | " | " | " | |
| 18 | " ..... | Stringers ..... | ..... | 19 520 | 36 700 | " | " | " | |
| 19 | " Trunk line... | " ..... | ..... | 29 800 | 52 300 | " | 1900 | " | |
| 20 | " ..... | Stringers and floor-beams.. | 70 | 20 000 (av.) | 40 000 (av.) | Iron. | " | ..... | Still in use, 1905. |

* Nos. 2 and 3 were old stringers cut off and used as deck spans, which accounts for the great disproportion between the flange unit stresses and the bearing stresses of the flange rivets.

It is the writer's practice to increase the stress in compression members by the following formula, $S_2 = S_1\left(1 + \frac{l^2}{18\,000\,r^2}\right)$, in which $S_1$ = the direct unit stress, $S_2$ = the maximum unit stress, $l$ = the length of the member, and $r$ = the radius of gyration of the member, in inches. This will be recognized as Gordon's formula as ordinarily used for pin-connected columns.

For computing the stresses in an improperly designed column, no general method is offered, as it is governed by the peculiarities of each case. It is in cases such as these that good engineering or structural judgment is most needed.

Many structures are unnecessarily condemned on account of rivets overstressed in shearing and bearing. The usual assumptions governing such cases are as follows:

*First.*—That the shearing strength of the material is equal to two-thirds of the tensile strength, and that the bearing strength is equal to twice the shearing strength;

*Second.*—That the entire stress transferred from one member to another must be considered as transferred entirely by the rivets in shearing and bearing, making no allowance whatever for the friction between the surfaces of the members;

*Third.*—That the diameter of the rivet is assumed as the diameter before driving.

These assumptions would give maximum allowable stresses for iron rivets of, approximately, 13 300 lb. per sq. in. in shear, and 26 000 lb. per sq. in. in bearing. The writer's experience has convinced him that riveted connections will not fail under any such limits of stress, and, in general, rivets will not begin to work loose until the unit stresses are nearly twice as great as these.

Table 1 gives some of the unit stresses in bearing of the flange rivets of built-up stringers of railway bridges examined or computed by the writer. All these bridges were on railroads carrying heavy traffic, and, in computing the stresses, full allowance was made for impact, etc. Not one of these stringers, as far as the writer is aware, ever showed signs of failure. The tensile flange unit stress is also shown, by way of comparison with the bearing stress.

The writer has considered that the reason for this great discrepancy between theory and observed results lies in the neglect of the element of friction between the two faces of the members in contact. This theory seems to be confirmed by the results of such tests as have been made.

Tests to determine the friction of riveted joints were made at the Watertown Arsenal, in 1882. These demonstrated that the friction developed between the surfaces of the plates of a riveted joint is a function of the area of the rivet section, and, therefore, is directly comparable with the shearing value of the rivet. These tests show the value of the friction to be about 14 000 lb. per sq. in. of rivet section for the single surfaces in contact, for a lap-joint, and about 18 000 lb. per sq. in., for joints providing two contact surfaces. As these values are higher than those usually allowed for rivets in shear, it follows that, in riveted joints, the working stresses are transmitted entirely by friction, and the shearing and bearing resistances of the rivets are not brought into play until much higher values of stress are reached.

It would appear that the ordinary working values of rivets in shear and bearing might well be increased, in the design of new work, and that the maximum allowable stresses in old structures might also be increased.

European bridge engineers have stated that European practice allows a much higher value of rivets in shear and bearing than American practice, and that they have never had trouble from this source. Therefore, it is perfectly safe to allow shearing and bearing values equal to the allowed value of the material in tension for shear, and, to double this amount for bearing, provided there are enough rivets in the connection, and that the workmanship is such as required to develop friction between the surfaces of the material. This would give values of, approximately, 22 500 lb. per sq. in. in shear, and 45 000 lb. per sq. in. in bearing, for rivet steel having a minimum elastic limit of 30 000 lb. per sq. in., to be used in examining old structures.

A set of experiments on riveted joints was recently made for a committee of the American Railway Engineering and Maintenance-of-Way Association.* These experiments were made on ninety

* Bulletin No. 62, American Railway Engineering and Maintenance-of-Way Association, April, 1905.

small riveted test pieces, which were tested to destruction, the failure occurring, in a majority of cases, by the shearing of the rivets at unit stresses of from 45 000 to 50 000 lb. per sq. in. of rivet section before driving, or by the breaking or splitting of the plates.

The values of the rivets in bearing upon the plates were approximately twice the shearing values at the point of failure. The conclusions drawn by the committee are repeated here:

"(1) That the resistance of a riveted joint against deformation by shearing forces, up to the yield point, is due to the friction between the surfaces held in contact by the rivets.

"(2) That the yield point of a riveted joint is reached when the shearing forces are equal to the friction of the surfaces held in contact by the rivets.

"(3) That the deformation of a riveted joint at the yield point is caused by the slipping on each other of the surfaces held in contact by the rivets, and is due to the diametral contraction of the rivets in cooling after they are driven, which leaves a space between the body of the rivet and the edge of the rivet hole.

"(4) That after the slip at the yield point has occurred and the rivet is brought to bear against the edge of the rivet hole, a deformation of the body of the rivet takes place with an accelerating increase in the resistance until the entire side of the rivet has been brought to bear against the edge of the rivet hole, and that the deformation continues beyond this point with a diminishing increase in the resistance until the ultimate strength of the rivet in shear has been reached and the breakdown occurs.

"(5) That lap joints, on account of the unsymmetrical distribution of material, deflect sideways under strain, throwing the rivets in tension, and thereby reducing the shearing forces between the surfaces held in contact by the rivets.

"(6) That fillers inserted between the main plates reduce the strength of a riveted joint, but that the full strength can be obtained by connecting the fillers to the main plates by additional rivets.

"(7) That the number of rivets connecting the fillers to the main plates should, for each intervening filler, be about one-third the number of rivets required in a similar joint without fillers, to obtain the same strength in both cases.

"(8) That the strength of a riveted joint with rivets of larger grip than about four times their diameter is decreased, as the length of the grip is increased.

"(9) That the number of rivets, in a riveted joint with larger grip of the rivets than four times their diameter, should be increased

at least one per cent. for each one-sixteenth of an inch increase in the grip above this length, to obtain the same strength as a similar joint with the grip of the rivets shorter than four times their diameter.

"(10) That a riveted joint, subject to forces always acting in the same direction, may safely be strained beyond the yield point up to a point where the rivets are brought to bear against the edges of the rivet holes.

"(11) That a riveted joint subject to forces alternating in opposite directions, may not safely be strained up to the yield point.

"(12) That, to obtain a minimum slip at the yield point, it is necessary that the holes in the component pieces should thoroughly match and that the driving tool should upset the rivet throughout its length so that it will thoroughly fill the rivet hole."

If the third conclusion be true, that rivets, in cooling, contract to such an extent that a space is left between the rivet surface and the side of the rivet hole, why is it that all rivets do not test loose under the inspector's hammer? It is the firm conviction of experienced inspectors that they can detect any rivet that is not completely upset. Is it possible that these men are mistaken, and that rivets which test loose do so only because the grip of the rivet heads on the plate is not great enough to prevent their movement?

This theory has been advanced before by European engineers, but the writer has seen specimens of riveted joints, which, when sawn through the rivet and polished, showed only a fine hair line dividing the rivet surface from the sides of the hole, which indicated a perfectly tight rivet. Of course, as is well known, in the case of long rivets, they are entirely upset only at the ends, and a space is often left between the rivet surface and the side of the hole at the center of the shank. Furthermore, the writer is loath to believe that the many thousands of rivets which he has tested and found to ring true could have done so unless the rivet sides were in contact with the sides of the hole, at least for some distance under the head.

Cannot the slipping of the plates, at the stress which is sufficient to overcome the friction between their surfaces, be explained on the ground of the compressibility of the metal, since apparently the slipping always occurs at a high stress. The experiments of M. Considère, in France, indicate slipping at a stress equal to ap-

proximately four-tenths of the ultimate shearing strength of the rivets, while the records of the experiments, conducted by the committee referred to, do not indicate any extraordinary movement of the plates when the slip occurred, subsequent increments of load causing movements of the plate comparable to the original slip. Is it not probable that the driving operation causes a state of compression to exist in the rivet metal and in the surrounding plate sufficient to take up the contraction due to cooling?

When the stress becomes sufficient to overcome the friction between the plates, the sudden reduction of the coefficient of friction would bring about half this stress suddenly upon the rivets, and considerable movement would be expected, due to the compression of the material, even if the rivets were perfectly tight.

There is another point, which concerns the design of new work as well as the investigation of old work, to which attention should be called.

In the design of plate girders it is the general custom, in the United States, to take the effective depth of the girder as the distance between the centers of gravity of the flanges, when obtaining flange stresses, and the distance between the rivet lines as the effective depth when obtaining the rivet values, which are dependent upon the stress transferred from the webs into the flanges in a given distance. Since the latter stress is simply an increment of the former, it would seem inconsistent to use different depths of girder for the two cases. Would not the more rational method be to assume the effective depth of the girder as variable, and use the same depth for both purposes?

At the ends of the girder there is no flange stress, and, therefore, the effective depth of the girder is evidently the distance from center to center of rivets, while at the center of the girder, considering the same to be uniformly loaded, there is no shear, and all the stress has found its way into the flanges. Evidently, then, the distance between the gravity lines of the flanges is the correct depth of the girder at this point, if the stress be uniformly distributed throughout the flange section, as it seems reasonable to assume.

The writer has found many cases of existing girders in which the maximum rivet stresses were found, not at the ends of the girder, but at an intermediate point; and he would recommend that,

in such cases, a depth intermediate between the distance from center to center of gravity of the flanges, and the distance from center to center of the rivet lines, be taken as the effective depth for all purposes.

There is another point which illustrates well the difference between rules for designing new structures, and those for investigating old ones.

It is common practice, in designing plate girders, to allow no part of the web to be considered as flange section. While this gives an added factor of safety to the structure, and may be commendable in designing new work, there can be no doubt but that the web will do its share of the work involved in resisting flange stresses, in spite of the prohibition, and this fact should be fully considered in determining the strength of an existing structure, as, in such cases, it is desirable to know the actual conditions of stress.

The writer is a firm believer in the use of standard specifications as a guide in designing standard structures, and believes just as firmly that they should not be followed in designing structures which are of an extraordinary or unusual nature, and should not be used when reporting upon the safety of a structure, which is, in itself, unusual, or is subjected to unusual conditions of loading.

The general principles of bridge design should constitute the engineer's sole guide in such cases, and his only purpose should be to determine the actual conditions of stress in the various parts of the structure, basing his computations on actual measurements, and "rock-bottom" principles, unhampered by the limitations and assumptions of a set of specifications gotten up for an entirely different purpose.

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# PAPERS AND DISCUSSIONS.

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## THE ECONOMICAL DESIGN OF REINFORCED CONCRETE FLOOR SYSTEMS FOR FIRE-RESISTING STRUCTURES.

### Discussion.*

BY MESSRS. H. T. FORCHHAMMER, ARTHUR W. FRENCH, IRVING P. CHURCH, B. R. LEFFLER AND GEORGE HILL.

Mr. Forchhammer.

H. T. FORCHHAMMER, ASSOC. M. AM. SOC. C. E.—Without doubt, reinforced concrete will be used instead of steel for many and various constructions, in the near future, and any contribution to the theory or practical design is warmly welcomed.

The speaker thinks that Captain Sewell has done right in placing the economical design in the foreground, but does not quite approve the way in which the problem has been solved.

The stress-strain curve, as advised by the author, is probably the best one available until the results of experiments—made especially for this purpose—are at hand.

In opposition to the author, the writer believes that total failure occurs when the stress in the steel reaches the elastic limit. Hence, the ultimate strength of the beam is reached when the steel is stressed to the elastic limit, or the concrete is compressed to its ultimate strength.

The considerations for economical design, which will be given herewith, will show that it is not always the cheapest beam which is designed for these two values simultaneously.

*Continued from March, 1906, *Proceedings*. See December, 1905, *Proceedings* for paper on this subject by John S. Sewell, M. Am. Soc. C. E.

Mr. Forchhammer.

The author advises the use of Equation 6 instead of Equations 1 to 5. If, in Equation 6, $a$ is replaced by the proportion of $d$ given on page 634,* this equation will give practically the same results as Equations 1 to 5, but, if $a$ and $d$ are considered as variables, as on page 637,* the connection between Equations 6 or 7 and Equations 1 to 5 is quite changed.

Suppose Equation 7 to be solved for $d$, using a value for $a$ which is smaller than the one given on page 634;* the result is a beam in which the concrete is stressed less than 2 000 lb. per sq. in. when the steel is stressed to its elastic limit. If—on the other hand—Equation 7 is solved for $d$, using for $a$ a value larger than given on page 634,* the result is a beam in which the concrete is stressed more than 2 000 lb. per sq. in. when the steel is stressed to its elastic limit.

The result of the author's economical considerations, therefore, is that, for concrete beams with reinforcement of low elastic limit, it is cheaper to proportion the beam with less steel than that given on page 634,* but the author says nothing about the relative cost of beams reinforced with various kinds of steel. This can very well be done, and the speaker disagrees absolutely with the author when, on page 636,* he says it is impossible—with Equations 1 to 5—to express the cost in terms of the ratio of cost of steel per cubic foot to the cost of concrete per cubic foot, because this ratio is entirely independent of the ratio between the maximum allowable stresses of the two materials. Just because these two ratios are entirely independent of each other it is possible to find a value for the last-named ratio, leading to minimum cost. To accomplish this the speaker will use Equations 1 to 4, and, instead of Equation 5, will use Equation 6.

With $b = 1, \frac{E_s}{E_c} = e$.

Let $F =$ the maximum compression in concrete.

Using Equations 3 and 1:

$$\frac{y_1}{1} = \frac{y_2}{\frac{t_s}{e\,F}} = \frac{d}{1 + \frac{t_s}{e\,F}}.$$

Substituting $\beta$ for $1 + \frac{t_s}{e\,F}$, and solving:

$$y_1 = \frac{d}{\beta},$$

$$y_2 = d\left(1 - \frac{1}{\beta}\right).$$

* *Proceedings*, Am. Soc. C. E., for December, 1905.

Mr. Forchhammer.

This, substituted in Equation 4, gives

$$a\,t_s = 0.57\,F \times \frac{d}{\beta},$$ which, substituted in Equation 6, gives

$$m = h \times d \times 0.57\,F \times \frac{d}{\beta}.$$

Substituting $\alpha$ for $\frac{0.57\,F\,h}{\beta}$, and solving:

$$d = \sqrt{\frac{m}{\alpha}}.$$

To express $h$ by $t_s$, Fig. 1 gives

$$h\,d = y_2 + n\,y_1,$$

$$h = 1 - \frac{1-n}{\beta},$$

for $$n = 0.64, \quad h = 1 - \frac{0.36}{\beta}.$$

Substituting the value of $a$ in Equation 9,

$$x = p \times 0.57\,F \times \frac{d}{\beta\,t_s} + d,$$

as $$0.57\,F \times \frac{h}{\beta} = \alpha,$$

and $$d = \sqrt{\frac{m}{\alpha}},$$

$$\frac{x}{\sqrt{m}} = \frac{1}{\sqrt{\alpha}} + \frac{\sqrt{\alpha}\,p}{h\,t_s},$$

as $$\beta = 1 + \frac{t_s}{e\,F},$$

$$h = 1 - \frac{0.36}{\beta}$$

$$\alpha = 0.57\,F \times \frac{h}{\beta},$$

it will be seen that $x$ is expressed in terms of $t_s$, $e$, $F$, and $p$.

As $e$ and $p$ are constants, $x$ is a function of $F$ and $t_s$ only; hence, for each value of $t_s$, there is a certain value of $F$, making $x$ a minimum, or, for each value of $F$, there is a certain value of $t_s$, making $x$ a minimum.

These values, naturally, are purely theoretical, and may be outside the practical existing limits; but as the special object is not to get an absolute minimum, but only a good economical design, the speaker is of the opinion that it may be of interest to find values for the relative cost of beams designed for various values of $t_s$ and $F$.

Mr. Forchhammer.

In the formula just developed,

$$\frac{x}{\sqrt{m}} = \frac{1}{\sqrt{\alpha}} + \frac{\sqrt{\alpha}\,p}{h\,t_s},$$

the first member, $\frac{1}{\sqrt{\alpha}} = \frac{d}{\sqrt{m}}$, is due to the cost of the concrete; the last member, $\frac{\sqrt{\alpha}\,p}{h\,t_s}$, is due to the cost of the steel. In Tables 3 to 7, $C$ has been substituted for $\frac{1}{\sqrt{\alpha}}$, and $S$ for $\frac{p\sqrt{\alpha}}{h\,t_s}$. In these tables, in accordance with the author's opinion, $p$ is assumed to be 72, and $e$ to be 15. The ultimate strength of concrete in compression is assumed to be 2 300 lb. per sq. in. The upper part of Table 3 is for medium steel, with an elastic limit of 33 000 lb. per sq. in. For the various percentages of steel, the speaker has calculated the compression in the concrete, represented by $F$; the depth of the beam, by $\frac{d}{\sqrt{m}}$; the cost of the concrete, by $C$; the cost of the steel, by $S$; the total cost, by $\frac{x}{\sqrt{m}}$; and the resisting moment is for a beam 1 in. wide and 12 in. deep.

It will be seen that the cheapest beams are those in which the percentage of steel is from 1.1 to 1.4, and that the cost does not vary much if the percentage is only a little outside of these limits.

The lower part of Table 3 is for hard steel, with an elastic limit of 57 000 lb. per sq. in. For the other items the values are the same as in the upper part of Table 3.

It will be seen that the cheapest beam is that in which the full strength of the concrete and the elastic limit of the steel are reached simultaneously. Here, also, a little variation in the percentage of the steel does not influence the cost very much; but, as there is no actual minimum value (but two independent curves intersecting at the minimum point), it is here more important to keep close to the right percentage.

To try these results on tests the speaker used a very interesting series of tests* made under the supervision of A. N. Talbot, M. Am. Soc. C. E.

The upper part of Table 4 is for 12-in. beams of medium steel (all in the series) with an elastic limit varying from 30 000 to 35 000 lb. per sq. in. This table shows the actual percentage of

*The results of these tests are published in Bulletin No. 1 of the University of Illinois Engineering Experiment Station, September 1st, 1904.

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steel; the final stress in the steel; the breaking moment, in inch-pounds per inch; and the cost,

$$\frac{x}{\sqrt{m}} = \frac{12}{\sqrt{m}}\left(1 + 0.72 \times \frac{100\,a}{d}\right).$$

From Table 3 is taken the breaking moment and cost, as calculated, assuming the elastic limit to be 33 000 lb. per sq. in.

TABLE 3.—COST OF REINFORCED CONCRETE BEAMS, WITH VARIOUS PERCENTAGES OF REINFORCEMENT.

MEDIUM STEEL.

| $100\frac{a}{d}$. | $t_s$. | $F$. | $\beta$. | $h$. | $a$. | Cost Data. $C = \frac{d}{\sqrt{m}}$ | $S$. | $\frac{x}{\sqrt{m}}$ | For $d = 12$ in., $m$. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.41 | 33 000 | 850 | 3.59 | 0.900 | 122 | 0.0906 | 0.0267 | 0.1173 | 17 600 | |
| 0.52 | 33 000 | 980 | 3.25 | 0.889 | 153 | 0.0809 | 0.0303 | 0.1112 | 22 000 | |
| 0.83 | 33 000 | 1 300 | 2.70 | 0.867 | 238 | 0.0649 | 0.0388 | 0.1037 | 34 200 | |
| 1.11 | 33 000 | 1 560 | 2.42 | 0.851 | 312 | 0.0567 | 0.0455 | 0.1022 | 44 900 | |
| 1.39 | 33 000 | 1 800 | 2.23 | 0.838 | 386 | 0.0510 | 0.0510 | 0.1020 | 55 300 | Minimum cost. |
| 1.56 | 33 000 | 1 940 | 2.14 | 0.832 | 429 | 0.0483 | 0.0543 | 0.1026 | 61 700 | |
| 2.03 | 33 000 | 2 300 | 1.96 | 0.816 | 546 | 0.0429 | 0.0625 | 0.1054 | 78 600 | |

HARD STEEL.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.42 | 57 000 | 1 490 | 3.55 | 0.899 | 216 | 0.0681 | 0.0206 | 0.0887 | 31 000 | |
| 0.70 | 57 000 | 2 020 | 2.88 | 0.875 | 349 | 0.0536 | 0.0270 | 0.0806 | 50 200 | |
| 0.87 | 57 000 | 2 300 | 2.65 | 0.864 | 427 | 0.0484 | 0.0302 | 0.0786 | 61 500 | Minimum cost. |
| 0.97 | 53 200 | 2 300 | 2.54 | 0.858 | 442 | 0.0476 | 0.0332 | 0.0808 | 63 800 | |
| 1.52 | 39 800 | 2 300 | 2.16 | 0 833 | 505 | 0.0445 | 0.0486 | 0.0931 | 72 600 | |

With one exception (Beam No. 9) it will be seen that the final stress in the steel varies between the limits 29 300 and 37 400, with an average of 32 900 lb. per sq. in. With the same exception there is also harmony between the ultimate moments and costs as they were in the actual beams and as they are calculated. It would seem that the calculated moments are somewhat too small for the small percentages and somewhat too large for the large percentages.

The lower part of Table 4 is for six beams of hard steel having an elastic limit of from 55 000 to 60 000 lb. per sq. in. In this table, also, there is evidence of harmony between theory and practice.

To complete the investigation, Table 5 shows the relative cost of beams reinforced with steel of various elastic limits.

Assuming the ultimate strength of concrete in compression to be 2 300 lb. per sq. in., it will be seen that the cost decreases with the elastic limit of the steel until this has reached about 100 000 lb. per sq. in. Any further increase in the elastic limit will not decrease the cost.

TABLE 4.—COST OF 12-IN. REINFORCED CONCRETE BEAMS WITH VARIOUS PERCENTAGES OF REINFORCEMENT. Mr. Forchhammer.

MEDIUM STEEL.

| Beam No. | Reinforcement in 12 × 12-in. beam. | Percentage of Steel. | Final stress in steel measured. | Breaking Moment, $m$, per 1 in. width of beam. | | Total Cost, $\frac{x}{\sqrt{m}}$. | |
|---|---|---|---|---|---|---|---|
| | | | | Actual. | Calculated from Table 3. | Actual. | From Table 3. |
| 19 | 3 ½-in. plain round..... | 0.41 | 37 400 | 21 400 | 17 600 | 0.106 | 0.117 |
| 21 | 3 ½-in. " " ..... | 0.41 | 32 900 | 18 700 | 17 600 | 0.113 | 0.117 |
| 9 | 3 ½-in. Ransome..... | 0.52 | 70 000 | 42 000 | 22 000 | 0.081 | 0.111 |
| 16 | 3 ½-in. plain square..... | 0.52 | 32 100 | 23 100 | 22 000 | 0.108 | 0.111 |
| 17 | 3 ½-in. " " ..... | 0.52 | 29 300 | 22 200 | 22 000 | 0.110 | 0.111 |
| 5 | 3 ½-in. Kahn..... | 0.83 | 30 600 | 30 400 | 34 200 | 0.110 | 0.104 |
| 10 | 3 ½-in. Thacher..... | 0.83 | 32 000 | 33 800 | 34 200 | 0.104 | 0.104 |
| 15 | 3 ½-in. " ..... | 0.83 | 35 000 | 36 200 | 34 200 | 0.101 | 0.104 |
| 14 | 4 ½-in. Kahn..... | 1.11 | 30 200 | 39 700 | 44 900 | 0.108 | 0.102 |
| 4 | 5 ½-in. " ..... | 1.39 | 33 800 | 49 000 | 55 300 | 0.108 | 0.102 |
| 27 | 4 ½-in. plain square..... | 1.56 | 34 900 | 58 300 | 61 700 | 0.105 | 0.103 |
| 22 | 3 ½-in. Kahn..... | 1.67 | 38 800 | 51 400 | 66 000 | 0.116 | 0.103 |

HARD STEEL.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | 3 ½-in. Johnson..... | 0.42 | 52 600 | 28 000 | 31 000 | 0.095 | 0.089 |
| 7 | 3 ½-in. " ..... | 0.42 | 58 300 | 30 300 | 31 000 | 0.091 | 0.089 |
| 2 | 5 ½-in. " ..... | 0.70 | 58 800 | 44 300 | 50 200 | 0.086 | 0.081 |
| 20 | 5 ½-in. " ..... | 0.70 | 65 200 | 46 600 | 50 200 | 0.083 | 0.081 |
| 13 | 7 ½-in. " ..... | 0.97 | 54 100 | 64 100 | 63 800 | 0.080 | 0.081 |
| 28 | 6 ½-in. " ..... | 1.52 | 50 300 | 72 400 | 72 600 | 0.093 | 0.093 |

TABLE 5.—COST OF BEAMS REINFORCED WITH STEEL OF VARIOUS ELASTIC LIMITS.

| $t_s$. | $F$. | $100\frac{a}{d}$. | $\beta$. | $h$. | $\alpha$. | Cost-Data. | | | For $d = 12$ in., $m$. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $C = \frac{d}{\sqrt{m}}$. | $S$. | $\frac{x}{\sqrt{m}}$. | | |
| 30 000 | 1 630 | 1.39 | 2.23 | 0.888 | 348 | 0.0536 | 0.0536 | 0.1072 | 50 100 | |
| 33 000 | 1 800 | 1.39 | 2.23 | 0.888 | 386 | 0.0510 | 0.0510 | 0.1020 | 55 300 | |
| 35 000 | 1 910 | 1.39 | 2.23 | 0.888 | 407 | 0.0496 | 0.0496 | 0.0992 | 58 600 | |
| 42 300 | 2 300 | 1.39 | 2.23 | 0.888 | 493 | 0.0451 | 0.0451 | 0.0902 | 71 000 | Minimum depth. |
| 50 000 | 2 300 | 1.07 | 2.45 | 0.853 | 456 | 0.0469 | 0.0361 | 0.0830 | 65 700 | |
| 55 000 | 2 300 | 0.92 | 2.59 | 0.861 | 435 | 0.0480 | 0.0318 | 0.0798 | 62 700 | |
| 60 000 | 2 300 | 0.80 | 2.74 | 0.869 | 415 | 0.0491 | 0.0283 | 0.0774 | 59 700 | |
| 70 000 | 2 300 | 0.62 | 3.03 | 0.881 | 381 | 0.0513 | 0.0229 | 0.0742 | 55 000 | |
| 80 000 | 2 300 | 0.49 | 3.32 | 0.892 | 352 | 0.0534 | 0.0188 | 0.0722 | 50 600 | |
| 90 000 | 2 300 | 0.40 | 3.61 | 0.900 | 326 | 0.0554 | 0.0160 | 0.0714 | 47 030 | |
| 100 000 | 2 300 | 0.34 | 3.90 | 0.908 | 305 | 0.0573 | 0.0140 | 0.0713 | 44 000 | Minimum cost.. |
| 120 000 | 2 300 | 0.24 | 4.48 | 0.920 | 269 | 0.0610 | 0.0106 | 0.0716 | 38 700 | |

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Naturally, this value for the elastic limit is purely theoretical, but the interesting point is, that with steel having an elastic limit of about 60 000 lb. per sq. in., practically the minimum of cost is reached, as the theoretical minimum is only 8% lower. (It must be remembered that this percentage is only part of the cost.)

Table 5 also shows that the saving effected by using hard instead of medium steel is but slight, compared with what it would be in a steel construction. Using steel with an elastic limit of 35 000 instead of 55 000 lb. per sq. in., the cost here considered will be increased by about 24%; and, assuming the part of the cost here considered to be about one-half of the total cost, it is only 12% cheaper to use the hard steel.

As medium steel is considered much safer than hard steel, for all structural purposes, especially where it is subject to impact, the speaker thinks it proper to consider the question whether the slight saving in cost really justifies the use of hard steel.

Another advantage in using medium steel is that the concrete is stressed less, hence the working stresses in the tension and also in the compression parts of the concrete are smaller; but, if medium steel is used, only very low working stresses should be allowed.

If medium steel, with an elastic limit of 35 000 lb. per sq. in., is used in a concrete having an ultimate strength of 2 300 lb. per sq. in., and a factor of safety of 4 is wanted, the working stress in the steel must be only, say, 9 000 lb. per sq. in., and in the concrete, say, 600 lb. per sq. in. As shown in Tables 3 and 5, it will be cheaper to use in the concrete a working stress of from 450 to 500 lb. per sq. in. with the 9 000 lb. per sq. in. in the steel.

In relation to T-beams, the speaker is in agreement with Captain Sewell. As steel having a low elastic limit does not utilize the full strength of the concrete in compression, even for a rectangular beam, the projecting flanges are not needed, and cannot act to decrease the dimensions of the beam. On the other hand, with steel having a high elastic limit, the full strength of the concrete is utilized in a beam of rectangular section; hence, the projecting flange will make it possible to increase the steel reinforcement without crushing the concrete. Therefore it will be proper to make $\frac{A}{b\,d} = \frac{1}{p}$, as proposed by the author, and then find $h$ from Equation 7.

If the full width of the beam which can be considered is $B = b + 2\,c$, it is necessary to inquire whether or not $\frac{1}{p} \times \frac{b}{B}$ is greater than the percentages given in Table 5. With $p = 72$ and $\frac{B}{b} = 3$,

$$100 \times \frac{1}{72} \times \frac{1}{3} = 0.46\%,$$

hence the equation can be used for steel having an elastic limit up to 80 000 lb. per sq. in. Mr. Forchhammer.

For steel having an elastic limit of 60 000 lb. per sq. in. the percentage in Table 5 is 0.80. Hence, for steel having an elastic limit up to 60 000 lb. per sq. in., the equation proposed by the author may be used if $\frac{B}{b} = \frac{1.39}{0.80} = 1\frac{3}{4}$, this is, if the projecting flange on each side of the beam is at least three-eighths of the width of the beam itself.*

In the foregoing the speaker has considered bending, but has not considered shear. The shear certainly has to be taken care of, as well as the bending; but, as it is evident that the cost of a well-designed web reinforcement is entirely independent of the depth of the beam, it is proper not to consider the web reinforcement when trying to find the most economical depth.

The speaker considers the web reinforcement very important, and, without doubt, the ideal construction is with attached web members. As designed by the author, this seems to be effective and cheap.

It seems to be still an open question whether, with attached web members, it is justifiable to assume that total failure will occur before the steel is stressed appreciably beyond the elastic limit. The author explains very logically his reasons for this assumption, but the speaker doubts whether the increase in the strength of the steel, due to web reinforcement, is appreciable. It seems natural to assume that the concrete will be crushed very shortly after the stress in the steel has reached the yield point. In any event, the speaker considers it safer to assume the ultimate strength of the steel at the elastic limit until reliable experiments have shown that it is above that limit.

On page 634† the author says:

"It is certain that it can never be economical to use enough steel to cause the beam to fail first by crushing the concrete."

Table 5 shows that, for steel having a very high elastic limit, it is cheaper, and, even for steel having a lower elastic limit, it may be economical—in order to decrease the depth of the floor—to use so much steel that the beam fails first by crushing the concrete. Beam No. 13, in the lower part of Table 4, is the most economically designed of all the six beams in that series, both theoretically and practically, and it failed by the crushing of the concrete.

On page 640† the author's expression, "maximum allowable per-

* If the neutral axis is below the projecting flange—which will generally be the case—this is a little on the unsafe side; hence it will be safer to allow the 60 000 lb. per sq. in. only if $\frac{B}{b}$ is, say, 2 or greater.

† *Proceedings*, Am. Soc. C. E., for December, 1905.

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centage of steel," is very misleading, as it leads one to believe that additional steel is dangerous, which is not the fact. Additional steel not only decreases the stresses in the steel, but, also, the stresses in the concrete, if the moment be assumed as constant.

Quite another matter, however, is the fact that it might be fatal in solving Equation 7 for $d$, using $t_s$ as the elastic limit of the steel used, when $a$ is larger than what the author calls the "maximum allowable percentage of steel." With excessive steel, the value of $t_s$ must be taken as that where the percentage used is allowable. An example will illustrate this: Under the assumptions made, Table 5 shows that, for steel having an elastic limit of, say, 55 000 lb. per sq. in., the most economical percentage is 0.92; then $\frac{d}{\sqrt{m}} = 0.0480$, and $\frac{x}{\sqrt{m}} = 0.0798$.

If the steel is increased to 1.07%, the allowable value for $t_s$ is 50 000 lb. per sq. in., $\frac{d}{\sqrt{m}} = 0.0469$, or 2.3% smaller than before; $\frac{x}{\sqrt{m}} = 0.0830$, or 4.0% higher than before.

If the steel is decreased to 0.70%, Equation 7, $m = h\,a\,d\,t_s$, gives:

$$m = 0.875 \times 0.70 \times d^2 \times \frac{55\,000}{100} = 337\,d^2;$$

$\frac{d}{\sqrt{m}} = 0.0546$, or 13.8% higher than in the first case;

$\frac{x}{\sqrt{m}} = 0.0546\,(1 + 0.72 \times 0.70) = 0.0821$, or 2.9% higher than in the first case.

It will be seen, therefore, that the most economical results are secured by using the percentages given in Table 5. Any smaller percentages will increase the cost as well as the depth of the beam. Any larger percentages will increase the cost, but decrease the depth of the beam, and the latter, under certain circumstances, may be of great value.

For these reasons, therefore, the author is incorrect in stating (page 640*) that "theoretical economy, based on relative costs, is not attainable." Theoretical economy, based on relative costs, is reached when what the author calls the maximum allowable percentages are used. The author is also incorrect in stating that any more than the economical percentage is wasted. As just shown, an

* *Proceedings*, Am. Soc. C. E., for December, 1905.

increase in the steel increases the strength of the beam; consequently, it is not wasted. Mr. Forchhammer.

With the assumption, made in Table 5, that the ultimate strength of the concrete in compression is 2 300 lb. per sq. in., the most economical percentage of steel for $t_s$ smaller than 42 300 lb. per sq. in. is 1.4. $\frac{d}{\sqrt{m}}$ will be seen to vary approximately in proportion to $t_s$, according to two straight lines which intersect at a minimum point where $t_s = 42\,300$.

The following equation, proposed by the speaker, is for a rectangular beam or floor slab:

$$d = \sqrt{m}\,(\alpha + \beta\, t_s),$$

in which $\alpha$ and $\beta$ have different values for various values of $F$. Assuming $F = 2\,300$, for values of $t_s$ greater than 42 300, $\alpha = +\,0.0360$, and $\beta = +\,0.218 \times 10^{-6}$. For values of $t_s$ smaller than 42 300, $\alpha = +\,0.074$, and $\beta = -\,0.69 \times 10^{-6}$. For other values of $F$, $\alpha$ and $\beta$ will have other values, and the point of intersection of the two curves will change. To find the point of intersection for other values of $F$, the equation,

$$a\, t_s = 0.57\, F\, \frac{d}{\beta},$$

should be used, as the point of intersection is where

$$d = p\, a, \text{ or } \frac{100\, a}{d} = \frac{100}{p} = 1.39.$$

$$\frac{t_s}{F} = \frac{57}{1.39\,\beta} = \frac{41}{\beta};$$

but $$\beta = 1 + \tfrac{1}{15} \times \frac{t_s}{F},$$

hence $$\frac{t_s}{F} = 18.4.$$

The speaker's formula, therefore, will be:

1.—For $t_s$ smaller than 18.4 $F$: Use 1.4% of steel and fix the depth of the beam in accordance with Equation 7, that is, $m = h\, a\, d\, t_s$, substituting for $h$, 0.85, and for $a$, $\frac{1.4}{100}\, d$; hence,

$$d = \sqrt{\frac{84\, m^*}{t_s}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ A$$

2.—For $t_s$ larger than 18.4 $F$: Make depth of beam

$$d = \sqrt{m}\,(\alpha + \beta \times 10^{-6}\, t_s) \ldots\ldots\ldots\ldots\ldots\ B$$

* This, it will be observed, is simply another form of Thacher's formula.

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The values of $\alpha$ and $\beta$, for various values of $F$ are:

| $F$. | $\alpha$. | $\beta$. |
|---|---|---|
| 1 900 | 0.040 | 0.282 |
| 2 100 | 0.038 | 0.244 |
| 2 300 | 0.036 | 0.218 |
| 2 500 | 0.034 | 0.200 |

The percentage of steel can then be fixed from Equation 7, using $h = 0.85$ and $m = 0.85\, a\, d\, t_s$, or

$$\frac{100\, a}{d.} = \frac{100\, m}{0.85\, d^2\, t_s} = \frac{118\, m}{d^2 t_s}$$

$$= \frac{118}{t_s (\alpha + \beta \times 10^{-6} t_s)^2}$$

In these formulas:

$m$ = the maximum moment per inch multiplied by the factor of safety required;

$a$ = the area of the reinforcing rods per inch of beam;

$d$ = the depth of the beam from the center line of the steel reinforcement to the ultimate fiber;

$F$ = the ultimate compressive strength of the concrete;

$t_s$ = the ultimate strength of the steel reinforcement (and for this the speaker proposes to use the elastic limit of the steel until it is plainly shown that a higher value is permissible).

*Example 1.*—A beam, 8 in. wide, is subject to a maximum bending moment of 100 000 in-lb. A factor of safety of 4 is required. The ultimate strength of the concrete is 2 200 lb. per sq. in., and the elastic limit of the steel is 30 000 lb. per sq. in.

$$m = 4 \times 100\,000 \div 8 = 50\,000.$$

As $\frac{t_s}{F} = \frac{30\,000}{2\,200} = 13.6$, and is less than 18.4, Equation $A$ must be used.

Percentage of steel = 1.4.

$$d = \sqrt{\frac{84 \times 50\,000}{30\,000}} = 11.82 \text{ in., say } 12 \text{ in.}$$

*Example 2.*—A beam, 6 in. wide, is subject to a maximum bending moment of 72 000 in-lb. A factor of safety of 5 is required. The ultimate strength of the concrete is 2 300 lb. per sq. in., and the elastic limit of the steel is 60 000 lb. per sq. in.

$$m = 5 \times 72\,000 \div 6 = 60\,000.$$

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As $\frac{t_s}{F} = \frac{60\,000}{2\,300} = 26.1$, and is larger than 18.4, Equation $B$ must be used.

$$d = \sqrt{60\,000}\,(0.036 + 0.218 \times 10^{-6} \times 60\,000) = 12.0 \text{ in.}$$

$$\frac{100\,a}{d} = \frac{118 \times 60\,000}{144 \times 60\,000} = 0.82 \text{ per cent.}$$

If it is of importance to decrease the depth of the beam as much as possible, $\frac{t_s}{F}$ should be assumed as equal to 18.4. Then $t_s = 18.4 \times 2\,300 = 42\,300$. $d$ can then be calculated either from Equation $A$ or Equation $B$.

Using Equation $A$:

$$d = \sqrt{\frac{84 \times 60\,000}{42\,300}} = 10.9 \text{ in.}; \text{ and } \frac{100\,a}{d} = 1.4 \text{ per cent.}$$

Using Equation $B$:

$$d = \sqrt{60\,000}\,(0.036 + 0.218 \times 10^{-6} \times 42\,300) = 11 \text{ in., and}$$

$$\frac{100\,a}{d} = \frac{118 \times 60\,000}{121 \times 42\,300} = 1.39 \text{ per cent.}$$

The results from these examples will be seen to check very closely with the results given in Table 5, and the speaker concludes that the equations proposed are sufficiently close approximations.

The speaker does not claim that the constants used for $p$, $e$, $F$, $t_s$, etc., will prove to be just the right ones. They may vary much, under different conditions, and only further experiments can fix their values.

To avoid any misunderstanding, the speaker wishes to state, finally, that the formulas proposed herein can only be applied where beams or floor slabs are exposed to actual bending. Wherever the arch action in the concrete is appreciable other formulas may be applied.

Mr. French.

ARTHUR W. FRENCH, M. AM. SOC. C. E. (by letter).—This paper is full of interest for designers of reinforced concrete, and the author will receive the gratitude of all for his excellent work.

Considering the many theories and formulas for the design of reinforced concrete beams, the greatest difference of opinion seems to be in the matter of using safe stresses or ultimate stresses in the steel and concrete.

The author proposes that the design be based upon the ultimate strength of the beam. The writer prefers the use of safe working stresses in the materials.

It is common practice to design wooden and metal beams on the safe working stresses. Our formulas for flexure are theoretically correct for such beams when the stresses are within the elastic limits. Outside of these limits, although the same formulas are

Mr. French. used, it is recognized that they are purely empirical, and that they depend upon tests for the values of the constants.

It is not impossible to construct formulas, for the ultimate strength of beams of homogeneous materials, based upon the properties of the stress-strain diagrams of the materials, but it is generally considered impractical. If the stress-strain diagram of concrete were not quite such a smooth and attractive curve, often with a marked resemblance to a parabola, it is doubtful whether anyone would attempt a theoretical formula for the ultimate strength of a beam of this material reinforced with another material.

An examination of many diagrams for concrete will show considerable variation in the relation between strain and stress as the stress increases from zero to the breaking point. The lines often resemble the parabola with its axis at the breaking point, but, with the richer concretes, the lines become more nearly straight. In all these diagrams, if the attention be confined to the part of the line from zero up to any stress that would be used as a working stress, it will be seen to be sensibly straight. Moreover, the elastic deformation for stresses from 0 to 500 or 1 000 lb. has been well determined for many concretes, and probably with greater accuracy than for stresses near the breaking stresses.

With the assumption of a constant ratio of stress to strain within the limits of the working stresses (and the assumption is close to the truth and slightly on the safe side), the design may be made with as much certainty as in the case of wooden or steel beams. Let the ultimate strength of the beams be a matter of test and the results be expressed by an empirical formula.

Fig. 28 gives the formulas used for safe working stresses and a graphical solution showing the relations between the unit stresses in the steel and concrete for various percentages of reinforcement.

It is important to note that the exact position of the neutral axis is of little importance as far as the strength, calculated from the steel element, is concerned. The effective arm of the couple changes very little with widely differing assumptions as to the value of $E_c$, or of the shape of the diagram for deformation of the concrete, and but little with the percentage of reinforcement.

The depth of concrete under compression and the total compression in the concrete, however, is affected greatly by the position of the neutral axis and also by the assumed shape of the diagram for concrete. Fig. 29 gives the formulas for the assumption of a full parabola for the shape of the stress-strain diagram between the limits, zero and the working stress, and considers the coefficient of elasticity to be 3 000 000 and 2 000 000 at the origin of the curve.

Fig. 30 is also for the parabolic distribution of stress, but is based on coefficients of elasticity of 3 000 000 and 2 000 000 at the

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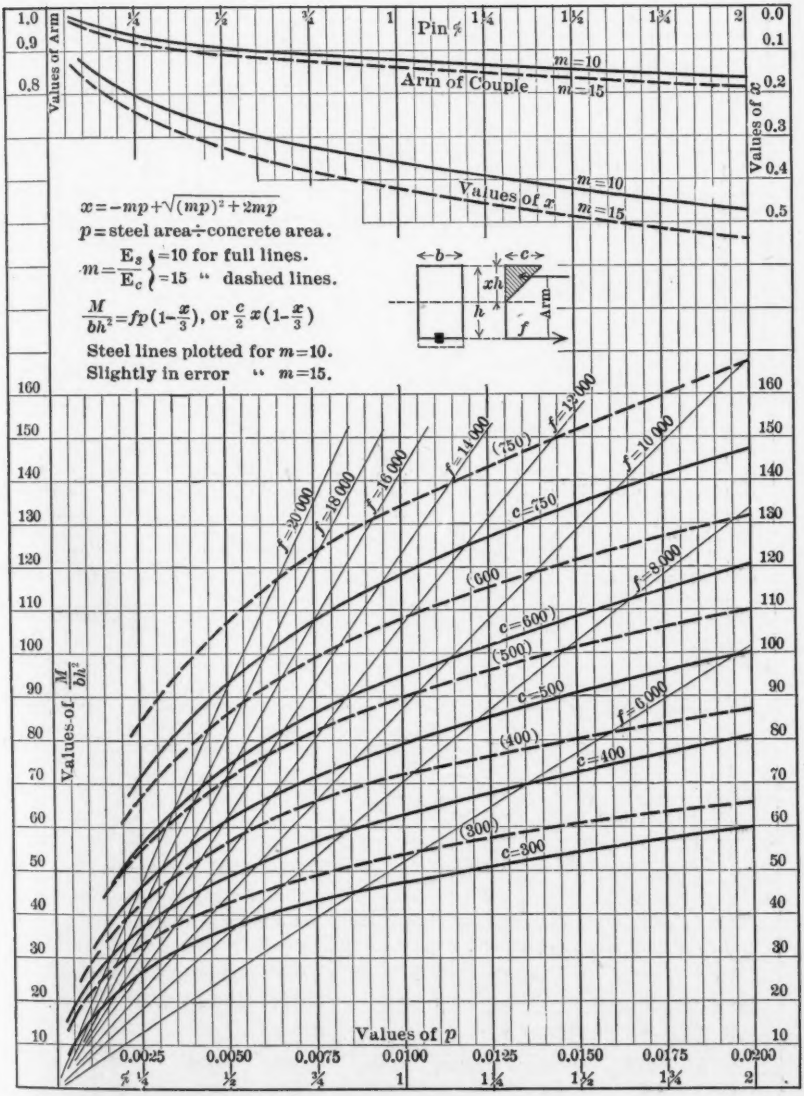



FIG. 28.

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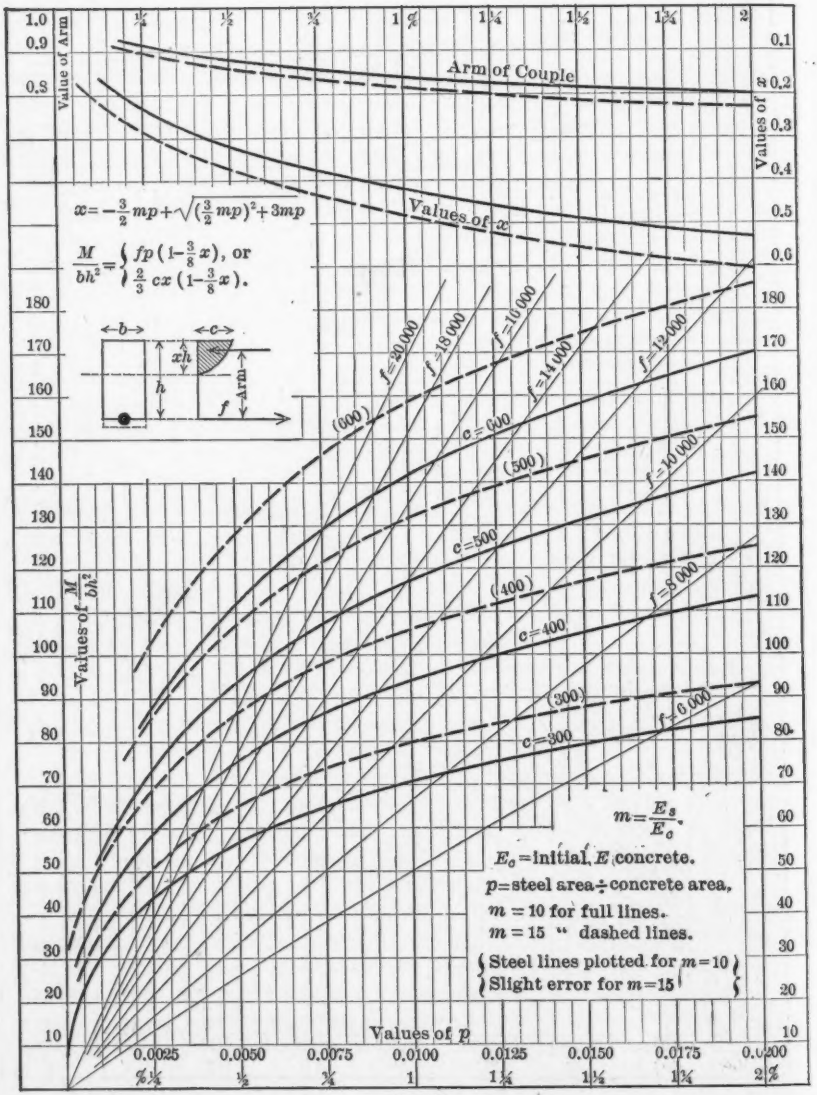



FIG. 29.

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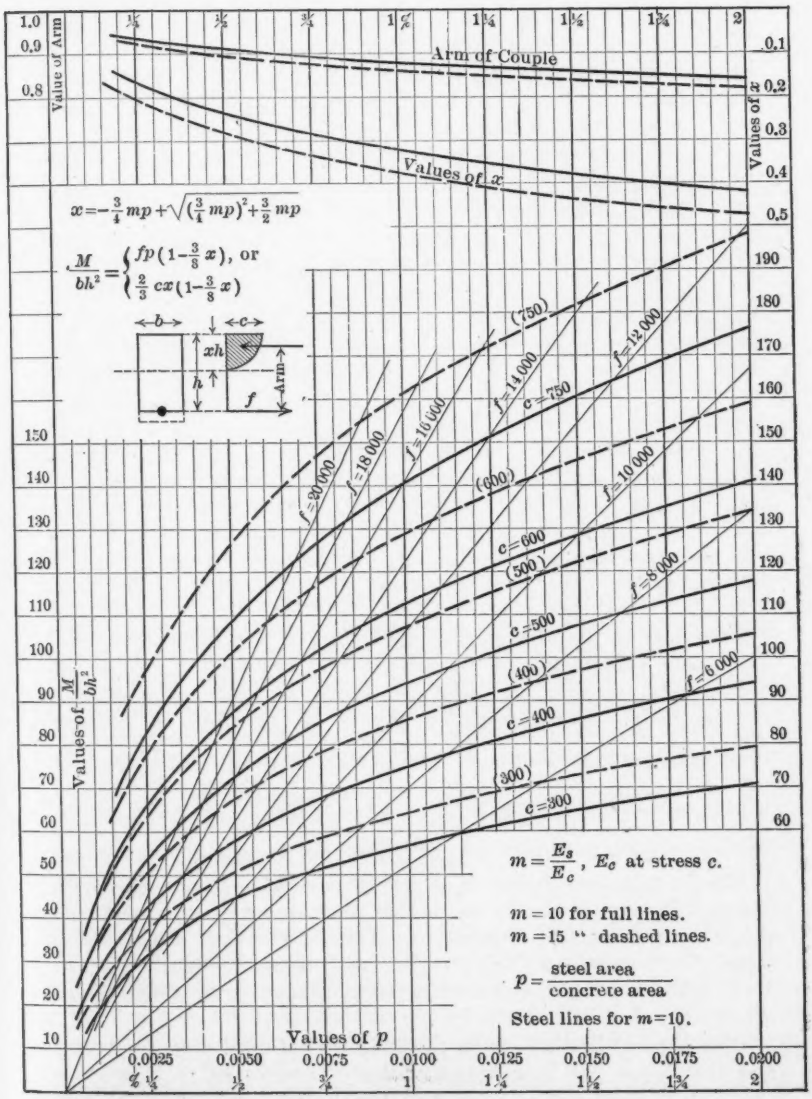



FIG. 30.

Mr. French. working stress. The assumption in the last case is equivalent to an initial coefficient of either 6 000 000 or 4 000 000.

The absurdity of assuming a full parabola for the stress distribution within a working limit of from 500 to 750 lb. has often been pointed out. Formulas based upon such an assumption may be made to give any desired results if the $E$ is chosen properly, but they must be considered as purely empirical, and the writer would prefer an empirical formula of the correct form.

The writer cannot agree with the proposed formula of Mr. Wason for general application. The assumption of the neutral axis in the center of the beam is in close agreement with theory for the percentage of steel in the examples, and, used by its author or other expert, within certain limits, it gives good results. It is certainly the simplest formula proposed, and for about 1% of steel reinforcement, is of great value. Its use is equivalent to allowing 750 lb. stress upon the outer fibers of the concrete if the straight-line formula is used as a test. Probably many beams which are calculated by certain formulas to give 500 lb. stress have nearer 750 lb. if tested by the straight-line formula.

Practical experience with many structures of concrete tested up to 2 000 lb. per sq. in. in straight compression, as well as laboratory tests of such beams, seems to show that if designed by the straight-line formula, with from 600 to 750 lb. stress in the concrete, they will possess ample factors of safety. It may sound better to talk of 500 lb., rather than a higher stress, but the truth is the thing desired.

The use of the straight-line formula for working stresses will give lower percentages of steel allowed in the section, or if high percentages are used, the allowable stress in the steel is reduced automatically. As an example of the use of Fig. 28, if the stress in the concrete is to be limited to 600 lb., and $\frac{E_s}{E_c}$ is taken as 15, and the working stress permissible in the steel is 16 000 lb., the value of $\frac{M}{b\,h^2}$ will be 72, for $p = 0.005$. If $p$ is 0.0065, the stresses will be 600 and 16 000 lb., and the value of $M \div b\,h^2$ will be 94. Where conditions demand, it may be wise to use higher percentages of steel, although this is not theoretically economical. Thus, if $p = 0.02$, the allowable stress in the concrete, of 600 lb., will determine the value of $M \div b\,h^2$ as 132, and the corresponding stress in the steel will be about 8 000 lb.

The natural limitations in the use of reinforced concrete beams and the desire for long spans or heavy load-carrying beams are constant temptations to over-steel the beams, and some formula which controls automatically the relation between the areas of steel and the stresses therein seems to be very desirable.

Mr. French.

Shear reinforcement is shown to be needed in most beams, both by analysis and by tests, and it is well that increasing attention is being given to the subject. In view of the comparatively small amount of steel needed to insure safety from failure by shear, it is the writer's practice to be rather liberal with such reinforcement. If stirrups are to be used at all, the added expense of furnishing and placing a liberal supply is small.

Undoubtedly the most effective form of shear reinforcement is that of rods attached rigidly to the tension bars, sloping up toward the supports, and extending well to the top, or even extending into the slab. The one form of patented reinforcement which well fills the requirement of rigid attachment does not always easily supply the requisite number and length of shear rods where they are needed most. Other forms of rigidly attached rods seem to be clumsy and expensive. If the shear rods are to be loose stirrups, they should be set vertically. Ease in placing the concrete and in providing the desired number of rods of the proper length cause the writer to prefer, in practice, the loose vertical shear rods.

There would seem to be no reason why the width, $b'$, of a slab assumed to act as a compression flange, should be limited to three times the width of the stem, $b$, if the proper reinforcement for shear at the section between the wings and stem be provided. Without reinforcement, the limit of $b' = 3\,b$ is well taken.

Mr. Church.

IRVING P. CHURCH, ASSOC. AM. SOC. C. E. (by letter).—In making a contribution to the discussion on Captain Sewell's valuable paper, the writer has in mind a brief, though fairly systematic, investigation of the relation between the cost and the dimensions, stresses, etc., of the ordinary concrete-steel beam or slab of rectangular section, with reinforcement on the tension side only. This treatment will be based on the assumption of the straight-line, stress-strain diagram for the concrete, and the tension of the concrete will be neglected (all loads and reactions being perpendicular to the beam and in the same plane). The notation adopted will be the same as that already used in the paper, but, for convenience, two additional symbols will be used, viz., $r$ and $e$, representing the ratios, $\frac{T}{F}$ and $\frac{E_s}{E_c}$, respectively. The latter ratio will be taken as constant.

Since the distances, $y_1$ and $y_2$, are superfluous, as far as formulas for actual design are concerned, they will be eliminated at an early stage, while the compressive stress, $F$, in the "outer fiber" of the concrete need not be directly expressed in the final formulas, being replaceable when desired by the equivalent quotient, $\frac{T}{r}$. Again, $T$ and $F$ may have any values within reasonable limits, and the

Mr. Church.

ratio, $\frac{T}{F}$, is not taken as equal to $\frac{t_s}{0.8 f_c'}$, necessarily.

The author's Equations 1 and 2 still hold in the present connection, and from them is derived:

$$y_1 = \frac{e\,d}{r+e} \qquad (1c)$$

The centroid of the compressive stresses being at a distance of $\frac{2}{3} y_1$ from the neutral axis, the arm of the couple formed by the total stress, $a\,b\,T$, in the steel, and, $\frac{F\,b\,y_1}{2}$, in the concrete, is $d - \frac{y_1}{3}$, and hence

$$a\,b\,T\left(d - \frac{y_1}{3}\right) = M \qquad (2c)$$

The equality of the total stresses mentioned gives rise to the relation, $\frac{b\,F}{2} y_1 = a\,b\,T$, that is, $a\,b = \frac{b\,y_1}{2\,r}$, which, combined with Equation 1c, leads to

$$2\,r\,a(r+e) = d\,e \qquad (3c)$$

If $y_1$ is now eliminated from Equation 2c, by the aid of Equation 1c, and if for all subsequent work a value of unity be assumed for the width of the beam, so that the bending moment, $M$, becomes $m = \frac{w\,l^2}{8}$ ($w$ being the uniform load per square inch of upper surface of the beam and $l$ the span), there is obtained

$$3\,m\,(r+e) = (3\,r+2\,e)\,T\,a\,d \qquad (4c)$$

Equations 3c and 4c are the only relations needed for design (aside from considerations of shearing stresses) for a beam of rectangular section with reinforcement on the tension side only. They constitute two independent equations, from which, if all the quantities concerned except two are given or assumed, these two may be determined, and hence should be regarded as constants.

If, however, all the quantities concerned in these two equations be given or assumed except three, these three are not determinate, but are variables; and by the aid of Equations 3c and 4c, a relation may be obtained between any two of the three variables; that is, any one of them may be expressed as a function of either of the other two.

For use in subsequent work the following relations, all derivable from Equations 3c and 4c, are here appended:

$$a = \frac{d\,e}{2\,r\,(r+e)} \qquad (5c)$$

$$a = \sqrt{\frac{3\,m\,e}{2\,r\,T\,(3\,r+2\,e)}} \qquad (6c)$$

$$d = (r + e)\sqrt{\frac{6\,m\,r}{(3\,r + 2\,e)\,T\,e}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7c)$$ Mr. Church.

The cost of a beam (of unit width), of fixed span and maximum bending moment, $m$, will now be expressed in terms of various variables, and the conditions of minimum cost investigated.

From the nature of the case, the only quantities which are not fixed at the outset, and hence would be available as variables, are four in number, viz., $a$, $d$, $r$, and $T$; so that four groups, of three in a group, may be selected, in turn, each group comprising three variables ($m$ is treated as a constant).

As to the question of cost, consider only the items, (3) and (4) (mentioned on page 637* of the paper), assuming the cost of a cubic foot of steel to be equal to $p$ times that of a cubic foot of concrete, and denoting by $x$ a number proportional to the total cost of the two materials. Then, as in the paper,

$$x = p\,a + d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8c)$$

As a first group of variables take $a$, $d$, and $T$. Then, from Equations 5c and 8c, is found:

$$x = \left[\frac{p\,e}{2\,r\,(r + e)} + 1\right] d \quad \ldots\ldots\ldots\ldots\ldots\ldots (9c)$$

which gives $x$ as a function of the one variable, $d$.

Here it is seen that $x$ is directly proportional to $d$, so that there is no mathematical minimum. Hence, for practical design, we have to take simply as small a value for $d$ as may be consistent with a maximum safe value for $T$ (one of the other two variables), while also ensuring a safe value for $F$, as implied in the assumed value of $r$.

For example, let $e = 16$, $r = 20$, $w = 8$ lb. per sq. in., $l = 100$ in. (so that $m = 10\,000$ in-lb.), and $T = 16\,000$ lb. per sq. in. With these values, then, from Equation 6c,

$$a = \sqrt{\frac{30\,000 \times 16}{40 \times 16\,000\,[60 + 32]}} = \sqrt{0.00815} = 0.0903 \text{ sq. in.},$$

and for $d$, from Equation 5c,

$$d = \frac{36 \times 2 \times 20 \times 0.0903}{16} = 8.12 \text{ in.}$$

This would make the percentage of steel $\frac{0.0903}{8.12} \cdot \frac{1}{100} = 1.10\%$ (referred to the concrete above the steel); and the value of $F$, implied in the assumption of $r = 20$, is $16\,000 \div 20 = 800$ lb. per sq. in.

Secondly, take $r$, $a$, and $T$, as variables. Equation 9c will serve in this case, also; that is,

$$x = \left[\frac{p\,e}{2\,r\,(r + e)} + 1\right] d \quad \ldots\ldots\ldots\ldots\ldots\ldots (9c)$$

* *Proceedings*, Am. Soc. C. E., for December, 1905.

Mr. Church. giving $x$ as a function of the one variable, $r$, $d$ being a constant in this case. Evidently, $x$ decreases with an increasing $r$. Here, again, there is no mathematical minimum for $x$ (for any positive value of $r$) so that a practical use of the relation would be to take as large a value for $r$ as would be consistent with a maximum safe value for $T$. For instance, with $T = 16\,000$ lb. per sq. in., $d = 10$ in., $e = 16$, and $m = 10\,000$ in-lb., it is found, from Equation 7*c* (solving by trial, since this proves to be a cubic equation), that the value of $r = 26.3$; which, in Equation 5*c*, gives a value of 0.0719 sq. in. of steel for $a$, implying 0.719% of steel (if the steel is compared with the concrete situated above it). With $r = 26.3$, the value of $F$ would be 609 lb. per sq. in. With values of $r$ smaller than 26.3, the cost would be greater, and both $T$ and $F$ would have smaller values than the above (in this case of constant $d$, etc., and variable $r$, $a$, and $T$); and neither material would be worked to its full (safe) strength.

Thirdly (and this is the most important and practical case), consider as the group of three variables, $d$, $a$, and $r$. If, in Equation 8*c*, there are substituted values for $a$ and $d$ from Equations 6*c* and 7*c*, there is obtained an expression for $x$ as a function of the one variable, $r$, viz.,

$$x = \sqrt{\frac{3\,m}{2\,T\,e}}\left[\frac{p\,e + 2\,(r+e)^{\,r}}{\sqrt{r\,(3\,r+2\,e)}}\right] \qquad (10c)$$

To obtain a value of $r$ for minimum cost, the differential coefficient of $x$ with respect to $r$ should be placed equal to zero, and the resulting equation solved for $r$; but this would be found to lead to an equation of such high degree that a simpler plan is to compute the value of $x$ for each of a number of values of $r$ and note the occurrence of a minimum $x$.

The writer has done this for seven values of $r$, ranging from 4 to 50, in an example in which there is given $m = 10\,000$ in-lb., $T = 16\,000$ lb. per sq. in., and $e = 16$; while $p$ may be taken as 75 (that is, let 20 cents per lb. be the cost of the concrete, and \$15 that of the steel).

Since the variable part of the expression for $x$ is the factor in the bracket, let the other (constant) factor be denoted by $C$. The following values for $x$ have been computed:

For $r = 4$, $x = 102.6\ C$
" $r = 9$, $x = 71.6\ C$
" $r = 16$, $x = 62.2\ C$
" $r = 20$, $x = 61.6\ C$
" $r = 25$, $x = 62.9\ C$
" $r = 36$, $x = 69.6\ C$
" $r = 50$, $x = 81.8\ C$

Mr. Church.

It is seen that in this case $x$ has a mathematical minimum, and that it is reached for a value of about 18 for $r$; and it is also noticeable that as $r$ changes from 15 to 25 the variation in the cost is comparatively small.

Therefore, it may be said that in this example the cost is a minimum for $r = 18$.* Hence, with $T = 16\,000$ lb. per sq. in. the value of $F$ would be 888 lb. per sq. in. If it were desired that the stress in the concrete should not exceed, say, 600 lb. per sq. in., this could be secured by adopting for $r$ the value, 26.6, and the resulting cost would be but little in excess of that (the minimum) corresponding to $r = 18$.

As to the values of $a$ and $d$, corresponding to $r = 18$ in this example, it is found, from Equation 7*c*, that $d = 7.54$ in.; and then, from Equation 3*c*, $a = 0.098$ sq. in. of steel; which is 1.31% of the part of the concrete above the steel.

As to the only remaining group of three variables, viz., $d$, $T$ and $r$, it may be noted that the term, $p\,a$, in the expression for cost, $x = p\,a + d$, is constant (since $a$ is assumed in this case), and that, consequently, the variable part of $x$ is directly proportional to the height, $d$, and will be a practical minimum when $d$ is made as small as possible consistent with a maximum safe value for $T$, one of the other variables. Hence, this case is virtually the same as one already treated. When the $d$ has been computed for a proper $T$ the corresponding values of $r$, and later that of $F$, are easily found.

Although the foregoing has been based on the simple assumptions of the straight-line, stress-strain relation, it is thought that the results would not have been very different if the parabolic form of curve had been used.

Mr. Leffler.

B. R. LEFFLER, ASSOC. M. AM. SOC. C. E. (by letter).—The writer has had in mind for some time the publication of a paper on steel-concrete formulas, but Captain Sewell's paper has served a somewhat similar purpose. The writer wishes to add the following remarks in the way of a partial discussion, and addition; they apply to the subject in general.

Nearly all writers have adopted the ultimate-strength method of designing, but the writer believes this is a mistake. The evolution of rational designing shows a continual substitution of simple formulas of wide application for complicated ones of narrow application. For instance, there was a time when column formulas were entirely empirical. At present they are rational in form, with, perhaps, empirical constants. In fact, nearly the whole science of the mechanics of materials is derived from Hooke's Law—a simple law of wide application.

The common beam formula has been hotly disputed in the past, because it did not represent the actual conditions at the ultimate

* A later solution by the calculus gives 19.3 instead of 18.

Mr. Leffler. strength period. It would seem that reinforced concrete formulas are passing through a similar period of development; and that, finally, a simple formula, having a straight line in its stress-strain diagram, will supersede them all.

The writer's experience in reinforced concrete has been confined to the simple beam, and arches.

It is rather astonishing that, in the voluminous discussions of the past few years, no one has attempted to present a rational method of designing a reinforced concrete section for combined thrust and moment, on the supposition that steel takes tension only and concrete compression only. Edwin Thacher, M. Am. Soc. C. E., presented a formula, some years ago, in which concrete is supposed to take tension.*

Writers who adopt the ultimate-strength method of designing seem to be unaware of the impassable difficulties they create in a design for combined thrust and moment. They thus forever bar the rational design of reinforced concrete arches. As is well known, at any section of an arch there may be combined thrust and moment.

It may be well to state that all formulas and methods of designing arches are based on the assumption of a straight line in the stress-strain diagram.

The writer has before him a pamphlet—widely circulated throughout the Middle West—which purports to apply the ultimate-strength method to arches. The author of the pamphlet uses the common elastic theory for locating the pressure curve—a parabola in the case cited—but, in designing the individual sections for combined thrust and moment, he attempts to use the ultimate-strength method. These are some of the vagaries in the development of reinforced concrete design.

In designing the sections of an arch, the writer first used Thacher's formulas,† but abandoned these in favor of a method in which concrete takes no tension. He presents the following as an easy and rational method of designing a section for combined thrust and moment.

Let Fig. 31 represent two short blocks, having steel on one side, as shown, and subject to an eccentric compressive load. This is a typical case in arch design. Then, granting a straight line in the stress-strain diagram, no tension will occur in the steel as long as the load acts within the middle third of the concrete section. The small strip of concrete on one side of the steel is neglected.

When the load is at the far edge of the middle third, the compression on the far edge of the concrete is twice the average, and tension in the steel is about to take place.

A movement of the load into the far third produces further com-

* *Engineering News*, September 21st, 1899.

† *Transactions*, Am. Soc. C. E., Vol. LV, p. 188.

pression in the concrete, and causes tension in the steel. It is evident that this extra pressure, and tension in the steel, is directly proportional to the distance of the point of application of the load beyond the far edge of the middle third. Mr. Leffler.

For simple beams, the writer uses the straight-line formulas, as given in "Concrete, Plain and Reinforced," by Taylor and Thompson.

The following is the writer's simple method of designing for combined thrust and moment:

The moment, for extra pressure at the far edge of the concrete and for tension in the steel, is equal to the distance of the point of application of the load beyond the far edge of the middle third,

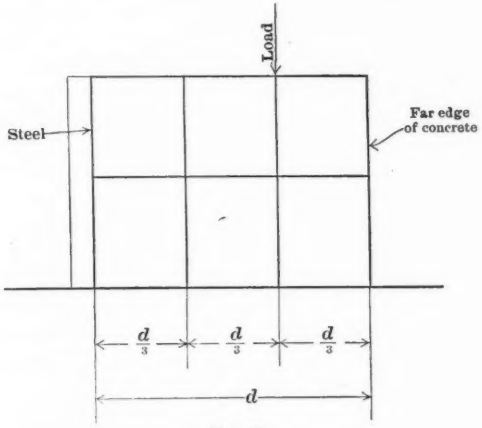



FIG. 31.

multiplied by the load. Use this moment as if it occurred in a simple beam, determining the extra pressure on the concrete, and tension in the steel. Add the extra pressure to twice the average pressure for the total pressure on the concrete at the far edge.

It is well to remember that the middle-third theory is based on a straight line in the stress-strain diagram, and cannot be used in the ultimate-strength method of designing.

The writer would like to see an advocate of the ultimate-strength method of designing attempt to show when steel takes tension in the above case!

The assumption of a straight line in the stress-strain diagram leads to simple formulas of wide application, and hence is bound to prevail. Of course, in this assumption, working stresses should be used, and not ultimate stresses.

Mr. Leffler. It seems to the writer that the present field of engineering literature on reinforced concrete is being turned into a vast mathematical gymnasium. An engineer is not primarily a mathematician, but only incidentally so.

Mr. Hill. GEORGE HILL, M. AM. SOC. C. E. (by letter).—Although reinforced concrete has been in use now for some few years, and the literature on the subject is becoming voluminous, a lack of agreement is still found in regard to facts. Relatively few tests have been made, and there are imperfections in the observations, tending to minimize the value of these tests, the majority of which have been for commercial rather than engineering purposes.

In glancing over the literature on the subject, the reader will notice that as a writer gains experience in the actual use of reinforced concrete his views regarding it change. He is more wary in using indiscriminate tests, is apt to make more for himself, and is less certain that he can solve all problems theoretically. This would indicate the desirability of less work with pencil and paper and far more work with a testing machine, before the application of the differential calculus to the results.

In certain tests made by the writer* he was struck by the similarity, in reasonably good slabs, of what might be called the load curve. All these tests were made with a portable hydraulic testing machine having a recording apparatus. Pains were taken to secure a reasonably uniform application of the load, and to record the deflection constantly, so that for each test there was a graphical representation which spoke directly to the eye and conveyed lessons which would otherwise have been lost unless considerable labor were expended in plotting the results. All the load curves indicated an elastic limit point for the combination, which also appeared in the deflection curve. In the writer's opinion, tests which stop short of the destruction of the object tested are of no value, and these constitute the bulk of the public tests during the past five years. Tests which do not indicate clearly the behavior of the piece under each increment of load, and those made for some especial purpose, without photographs, are of but little value, as the observations are open to dispute; therefore one can understand the author's desire for further tests.

Another serious difficulty is the lack of uniformity in the concrete. In the writer's opinion, therefore, the two most fruitful subjects for present investigation are the production of a concrete by commercial methods having fairly uniform characteristics which can be predetermined, and the testing to destruction of reinforced concrete members, under conditions which will secure graphic

* *Transactions*, Am. Soc. C. E., Vol. XXXIX, p. 617.

records of the load, its rate of application, the deformation at each instant, and the appearance of the piece tested at certain critical periods. Mr. Hill.

The author, on page 636,* states as follows:

"Therefore it seems justifiable to assume that a formula such as Equation 6 can be made just as accurate as any of the forms of Equations 1 to 5, especially if its constants be determined from tests designed with that end in view."

With this, the writer is in full accord. To a considerable extent, it supports the view he expressed in his paper† presented in April, 1898. While engineers may feel that it is too simple a solution for men of their mathematical attainments, yet, as they are charged with the duty of getting full value for their employers' time as well as their own, they should realize that the present state of the art admits of nothing better.

The writer doubts very much the value of the theoretical discussion of maximum economy by the methods of the calculus. Not only does the cost of the aggregate vary in different localities, but it varies constantly in the same locality. Owing to the beneficent rule of the labor unions, one may in one locality pay for labor at $1.75 per day, to-day, and six months later be required to pay $4 per day for the same work. During one month it may be found that one form of deformed steel bar can be had cheapest, and the next month some other form. It may be permitted on one job to use a certain style of form, or centering, which is relatively inexpensive and can be used repeatedly, but the next job may be so different that none of the former centering is available. Therefore, it follows that whatever may be the most advantageous for one job may be very uneconomical for the following one. The writer believes that no formula can be devised which will cover these conditions, and be used by a busy man.

In the ninety-four tests published in the writer's paper, previously referred to, he observed in no case any necessity for web reinforcement, and, in properly designed commercial structures, he doubts the necessity or desirability of such reinforcement. In relatively deep and slender T-beams it may be necessary, but it is questionable whether or not it is commercially desirable to design such beams.

The writer is heartily in accord with the following statements by the author: on page 626,* in regard to the impression of the extreme accuracy of the complicated formula, which is not at all justified; on page 630,* in regard to the desirability of taking conservative values for the maximum allowable stresses; on page 634,* in regard

* *Proceedings*, Am. Soc. C. E , for December, 1905.

† *Transactions*, Am. Soc. C. E., Vol. XXXIX, p. 617.

Mr. Hill. to the experimental determination of the maximum allowable percentage of reinforcement; on page 636,* heretofore referred to; on page 640,* that the best that can be done is to use as large a percentage of steel as the concrete will stand; on page 651,* that a mechanical bond is to be preferred to simple adhesion; on page 656,* that it is of importance that the floor slab and the part of the beam or girder below it should be bonded together; and paragraph 6 on page 659.*

In regard to the statement, on page 654,* concerning the dehydration of cement, the facts may be as stated by the author; the conclusion that this damaged material must be removed does not follow, for, if the tensile strength of the cement is neglected in the computations, this material is only used as a protection for the steel, and if it performs that function it might as well be left. It will perform that function if a wire netting or other similar substance be used for the sole purpose of retaining the cement around the reinforcement. It is to be earnestly hoped that this paper will attain its main object, as explained in the last paragraph on page 659.*

Engineers who design reinforced concrete should come to an agreement in regard to the most desirable method of making tests; in regard to practicable formulas which can be applied in design; in regard to formulas applicable to floor slabs with numerous supports; in regard to the shrinkage of slabs and walls in setting; in regard to a provision for either the elimination or localization of cracks; and in regard to the commercial limitations which, in general, should apply in the design and construction of reinforced concrete buildings.

* *Proceedings*, Am. Soc. C. E., for December, 1905.

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# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## NEW FACTS ABOUT EYE-BARS.
## Discussion.*

BY MESSRS. HENRY B. SEAMAN, MANSFIELD MERRIMAN, ALBERT J. HIMES, A. W. CARPENTER AND JOHN THOMSON.

HENRY B. SEAMAN, M. AM. SOC. C. E.—The matter of chief in- Mr. Seaman.
terest in connection with these full-sized tests is that, on 50-ft. bars, they offer a confirmation of the specimen tests made by Bauschinger years ago. Mr. Cooper's tests on eye-bars show a permanent set at a strain of about 12 000 lb. per sq. in., while his specimen tests indicated an elastic limit of about 35 000 lb. If his eye-bars had been still longer, it is possible that a permanent set would have been observed at even a lower strain. This, to the speaker's mind, is a very satisfactory confirmation of the deduction of Bauschinger that, after a strain is once applied, the elongation is never entirely eliminated, although it may gradually decrease if allowed time for rest.

These tests, the speaker believes, confirm the statement made by him in a paper† upon the Launhardt formula, that the experiments

* This discussion (of the paper by Theodore Cooper, M. Am. Soc. C. E., printed in *Proceedings* for January, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Communications on this subject received prior to May 26th, 1906, will be published subsequently.

† *Transactions*, Am. Soc. C. E., Vol. XLI, pp. 141 and 146.

Mr. Seaman. of Wöhler entirely destroy the theory of the perfect elasticity of metals as formerly accepted, and require that the term be abandoned and a new definition sought. Since that date the term, "yield point," has gradually replaced the old term, "elastic limit."

Mr. Cooper's experiments are valuable in demonstrating the necessity of considering the results of refined testing in large structures.

Mr. Merriman. MANSFIELD MERRIMAN, M. AM. SOC. C. E.—The full-sized drawings exhibited by the author show the distortions in the eye-bar heads more clearly than the speaker has heretofore seen. From these lines it is possible to study the actual distribution of the stresses throughout the metal, and probably a more precise knowledge might be obtained than that which we now possess. The lines, ruled on the head before making the test, were parallel and normal to the length of the bar forming 1-in. squares, and the distortions of these squares indicate the nature and the relative intensities of the stresses. Where a square is seen to be distorted into a rectangle, one side being shorter and the other longer than 1 in., it is known that there existed compressive and tensile stresses at right angles to each other. Where a square is distorted into a rhombus, it is known that shearing stresses also prevailed. The speaker regards these drawings as of much interest and value, and hopes that the author may be able to publish one or more of them for the benefit of the engineering profession.

Referring now to the general question brought forward by the author, it seems to be proved by the tests that the elastic limit of the eye-bar, as a whole, is reached before that of the bar proper. It is not difficult to see that this is entirely due to the high compressive stress in the eye-bar head at the back of the pin, this being due to the small bearing surface between the pin and the head. The usual rule for determining the bearing compressive stress, by dividing the total tensile load by the diametral area of the pin hole, is, of course, a rough approximation, and it is certain that, with the usual clearances, the actual stress between the pin and the eye-bar head is very much greater than given by this rule. As a consequence, the compressive elastic limit of the metal in the head is exceeded before the tensile elastic limit of the metal in the bar proper is reached. Fortunately, the shape and size of the eye-bar heads have been so proportioned by experiment that rupture almost always occurs in the bar, and hence the author's conclusions throw no distrust upon the eye-bar system of bridges, as far as safety is concerned. His investigation, however, is of value and importance in computing the camber of long spans, and also for cases where the deflections of the ends of projecting trusses require to be computed.

Mr. Merriman.

In order to decrease the compressive stress in the metal back of the pin, it has been suggested to increase the thickness of the head of the eye-bar, and also to use a harder steel for the head. While the head can be made thicker, it is doubtful if it would be expedient to do so with such large eye-bars as those used in the Quebec Bridge. The use of harder steel for the head does not seem practicable unless the bar itself is also of the same grade of steel; in this case the elastic limits of both head and bar would be higher, the allowable unit stresses would also be taken higher, and, hence, the same phenomena as before would occur.

A third method that has been suggested is to cut the eye-bar hole of oval shape, the shorter diameter of the oval being a little larger than the diameter of the pin, while the longer diameter, which is parallel to the axis of the bar, is sufficiently large to give ample clearance. The curvature of the oval at the back of the pin should be greater than that of the pin, so that the pin, when first brought into bearing, does not quite touch the back surface of the hole, but bears along the head at two places on each side. The curve to be used should be such that, for a certain tensile stress in the bar, say, 15 000 lb. per sq. in., the radial compressive stresses between the pin and the head would be closely equal over an arc of 120°; if this can be attained, the intensity of the radial compressive stress will be less than 18 000 lb. per sq. in. The theoretic determination of this curve is not an easy matter, for the pin, also, is deformed as the stress increases, but a few experiments would undoubtedly result in producing an oval hole for which the distortions of the head would be very much less than those shown in the author's drawings. While the cutting of such holes would add somewhat to the cost of the eye-bars, it may be noted that the difficulty of inserting a pin through many bars in erection would be much diminished, since the oval holes would furnish ample longitudinal clearance.

Mr. Himes.

ALBERT J. HIMES, M. AM. SOC. C. E. (by letter).—That an eye-bar is known to be permanently elongated in the pin-hole when the strain in the body is not more than 12 000 lb. per sq. in. is a startling fact, and should have been discovered before. In now bringing the matter before the Society, Mr. Cooper has added one more important service to the generous list which he has already given to the profession.

Although it is not found in practice that bridges are developing a deflection such as would be caused by elongation of the pin-hole, and, in taking down numerous old bridges which have been subjected to loads far beyond those contemplated in their design, no deformation of the pin-hole has been noticed, these facts merely demonstrate, as in the case where one of a pair of eye-bars carries the whole load, that the assumptions of loading and factor of safety

Mr. Himes. are so liberal that defects, like this lack of strength in the pin-holes, have not produced any noticeable effect in working structures.

Such defects, however, are elements of weakness which greatly reduce the supposed factor of safety and render of small value the liberal sections brought into use by some of the impact formulas.

The author's discovery will also do much good indirectly by checking a tendency toward over-confidence in the perfection of the art of bridge building. That there is still something to discover is very evident, and the need of greater caution is plainly indicated.

A theoretical discussion of the effects on the pin-hole of tension in the bar gives results so much in accordance with those described by the author that it will be presented for consideration.

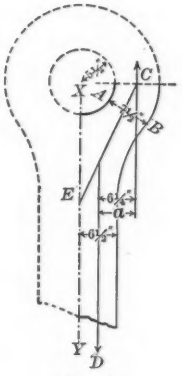


FIG. 7.

If an eye-bar be imagined to be divided longitudinally on the center line, and each half of the bar to carry its proportion of the tension independently of the other half, and then, if the head of the bar be cut through the center of the pin-hole at right angles to the axis of the bar, the result is a free body, shown in Fig. 7. This free body is acted upon by only two forces: tension in the body of the bar and a parallel tension in the head; but the two forces are separated by a distance, $a$, thus forming a couple. The moment of this couple must be resisted by a section of the head, $A$, $B$, and, in a specific case, the computation of the outer fiber stresses in this section will show that the usual working stress in the body of the bar produces stresses in the section which exceed the elastic limit.

Assume a bar 1 in. thick.

Assume a unit stress of 12 000 lb.

Tension at $D = 6\frac{1}{2} \times 12\,000 = 75\,000$ lb.

" " $C = 75\,000$ lb.

Arm of couple $= 6\frac{1}{4}$ in.

Moment of couple $= 469\,000$ in-lb.

Section $A\,B = 7\frac{1}{2} \times 1$ in. $= 7\frac{1}{2}$ sq. in.

Moment of inertia of $A\,B = 35.2$.

$$\text{Outer fiber stress at } A = \frac{M\,e}{I} = \frac{469\,000 \times 3.75}{35.2} = 49\,960 \text{ lb.},$$

which exceeds the elastic limit.

This condition agrees precisely with those reported by the author. He discovered compression at $B$ and elongation at $A$, and a permanent deformation when the unit tension at $D$ was 12 000 lb.

With the change of shape of the pin-hole, there must come a re-distribution of stress in the section, $A\ B$, so that the tension at $A$ will decrease and the compression at $B$ will be changed to tension. If the direction of the tension at $C$ be changed so as to pass through the head and intersect the axis of the bar at $E$, there is no longer a couple, and the tendency to deformation which it produced in the section, $A\ B$, has ceased; or, it may be said that a second couple has been formed by the lateral pressure against the pin and its corresponding resistance in the section, $X\ Y$, this couple acting in a direction opposed to the first couple, and therefore relieving the bending stress in the section, $A\ B$. This condition agrees well with the fact that after a slight stretch at $A$, the pin-hole is not generally ruptured, although the bar breaks in the body under a tension four or five times as great as that which caused the first deformation in the pin-hole. Mr. Himes.

Mr. Cooper discovered that a slight variation in the pin-hole clearance produced no appreciable effect in the deformation of the bar, and this fact also agrees with the theory, since a maximum variation of, say, $\frac{1}{16}$ in. is very small, compared with the arm of the couple.

In attempting to meet the requirement that bars tested to destruction shall break in the body rather than in the head, the manufacturers, apparently, have rested content with their success, and have paid little attention to the character of the deformation.

If the section, $A\ B$, could be given a moment of resistance great enough to keep the tension at $A$ well below the elastic limit, a condition which exists in the riveted flat bar, Fig. 4,* the defect would be corrected. Another remedy would be to alter the shape of the pin-hole and head to conform approximately to that due to final distortion. The latter method would not be perfect, but it would greatly lessen the defect. The bar would still have to stretch enough to come to a bearing on the sides of the pin, after which it might be fairly assumed that the bending moment has been eliminated. The manufacturers would find some difficulty in making the elongated holes, but the tests appear to indicate that an improvement is needed.

The author's conclusion, that bars of high tensile strength are to be preferred because they exhibit less deformation in the tests, would seem to be unsound, because such bars would be strained to the yield point in the section, $A\ B$, as well as bars of softer material, and, if steel must be deformed, it is well known that the softer grades are safer.

While eye-bars are under consideration, the writer desires to say something in reference to annealing. There seems to be a prevalent idea that the full-sized test is satisfactory if the bar does not break

* *Proceedings*, Am. Soc. C. E., for January, 1906, p. 24.

Mr. Himes. in the head. That result is assumed to prove the success of the bridge shop; and previous specimen tests have shown the character of the mill product.

Fractures partially crystalline are very common, and brittleness sometimes appears. These defects, in all probability, are due to heat treatment, and, as the bars have been annealed, they cannot be charged to the rolling mill. The full-sized test should be a test of annealing as well as a test of the workmanship on the heads, and there can be no true test of annealing unless a bar is broken from every charge of the annealing furnace.

The annealing of eye-bars has long been subject to the personal skill and supposed infallibility of men who, though faithful and skilful beyond the average, have, nevertheless, a poor conception of the scientific properties of steel. The importance, in annealing, of a uniform and rapid heating to a temperature, not too high, and of uniform and fairly rapid cooling, is not generally understood. Ridsdale has shown the effects of too high a temperature and of chilling,* and bars that bore all the evidence of such treatment have been seen by the writer. It would seem that the substitution of a pyrometer for the time-honored color test would afford a more certain control of the temperature and be another step in the march of progress.

Mr. Carpenter. A. W. CARPENTER, ASSOC. M. AM. SOC. C. E. (by letter).—The author states that the failure of the usual assumptions, as shown by his investigation, is not of much importance in ordinary bridges on account of low unit stresses. It would seem to the writer that the stresses in ordinary bridges are frequently, if not generally, high enough to come within the range of those which are shown to be serious. With the increase of loads and with the impact, in the case of railroad bridges, the nominal stresses for which the structures are designed are greatly increased, and the details should be such as to take care of any increase in the stresses as well as in the main sections.

In view of the results obtained by the author, the present generally-adopted design of eye-bar heads is defective, even for ordinary structures, especially as the tendency is toward smaller heads. The author's experiments were conducted upon bars with heads larger in proportion than are now furnished in ordinary practice. The excess percentage through the eyes of the bars tested is shown to vary from 39 to 69%, with one exception, in which the excess was 31 per cent. The largest bridge concern in the country has, for a standard, a head with 30% excess of section through the eye, and guarantees the development of the full strength of the bars with such heads. It would appear from the author's tests that the

* *Engineering News*, Vol. 46, pp. 238 and 276.

stretch of the pin-holes in such heads, due to stresses within work- Mr. Carpenter.
ing limits, would obtain in greater degree than with the larger heads. It would seem, therefore, that the manufacturers should change their standards to produce larger heads, even at the expense of some metal and room for clearance. This would seem to be a primary step in the right direction. As pointed out by the author, however, something more is necessary. He shows that reducing the pin clearances and increasing the size of the pins does not affect the results.

He calls attention to the superiority of harder steel, and the tests appear to confirm this superiority. The writer believes that the steel used for eye-bars and other annealed members should be of a harder grade than that used for unannealed material, so that the finished work may be more nearly of the same strength throughout. With the added advantage of stiffening the pin-holes, this would surely seem to be the proper selection of material. This, of course, is in line with the author's suggestion, his other recommendation being to stretch the eyes longitudinally before final boring. The latter may be practicable, but seems to be a little doubtful.

The writer would offer the following suggestion: that the heads of the bars be made thicker than the bodies, a method which was extensively used at one time. This would seem to be the most efficient method of decreasing the maximum pressure of the pins on the pin-holes. This pressure, owing to the necessary clearance of the pin, however infinitesimal, must be a variable pressure, having a maximum at the back of the pin-hole in the line of stress. This maximum pressure is reduced directly in proportion as the head is thickened. The section in the head could thus be very rapidly increased without increasing the diameter, and the manufacture of such heads would seem to present no difficulties. The disadvantages would be in the increased space occupied in packing, the increased length, and, probably, in the increased strength required for the pins. A minor advantage in the thickening of the heads would be the greater separation of the bodies of the bars, as these sometimes lie too close for painting. It is possible that a very slight thickening would give the desired result, but this is a matter which it would only seem possible to prove by experiment.

An old handbook of the Phœnix Iron Company gives a table of dimensions of thickened eye-bar heads, which shows the range of thickness varying from $\frac{1}{4}$ to $\frac{5}{8}$ in. for bars up to 6 in. in width. The excess section obtained varies from 43 to 87 per cent. The material, of course, was iron, and the writer understands that the heads were formed partially by piling and welding, and partially by upsetting.

The writer's suggestions, summarized, would be, to make some bars with heads of the usual circular shape, and with a section through the pin-hole 50% in excess of the body of the bar, using

Mr. Carpenter. medium steel running to the highest limit of tensile strength (70 000 lb. ultimate strength), with heads thickened, say, 25% over the body of the bar, and test these for the stretch of the pin-holes on the lines followed by the author. Some change in the ordinary design and method of manufacture should be made to remedy the defect pointed out.

Mr. Thomson. JOHN THOMSON, M. AM. SOC. C. E. (by letter).—The following observations, while not derived from a line of application similar to that described by Mr. Cooper, may yet have some interest, and indicate a line of further experimentation which, if carried out properly, may cast additional light upon the subject.

As to the statement:

"We have assumed that a set of bars carefully bored to an exact length would all pull to an equal strain, as long as the elastic limit measured on the body of the bar was not exceeded."

The writer can say that in his experience with short connecting rods, used for heavy duty on printing and embossing machinery, it has been known, for a considerable time, that the design of the eyes and the relative proportion existing between the bearing surfaces thereof and the pins upon which they act, are factors of the first importance.

Thus, if the eye-bars described in the paper are regarded as connecting rods to be used in tension on a machine, then, in the writer's opinion, the reason they failed in the manner set forth would be due to the fact that the bearing surfaces, as between the bores of the eyes and the pin, have not sufficient area.

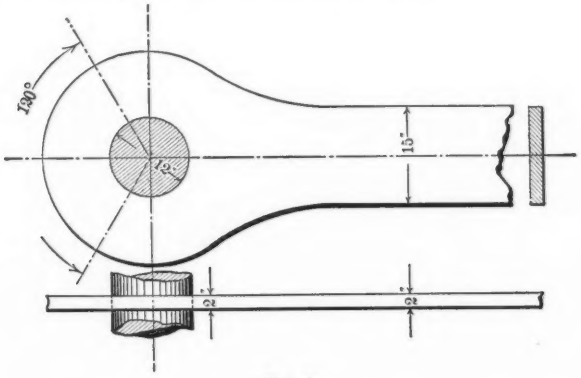



FIG. 8.

Fig. 8 is a view of a 15-in. bar, 2 in. thick, with a 12-in. pin. The effective arc of contact on such an eye and pin will not exceed 120°; if loosely fitted, as stated, it will hardly exceed, say, 90°, which

Mr. Thomson.

is the arc of contact in primary intimate contact. But, assuming the maximum, or 120°, the effective area in contact to resist the pull of the bar will be approximately 25 sq. in. The area of the rod, $15 \times 2 = 30$ sq. in., which, when subjected to a stress of 24 000 lb. per sq. in., gives a total test load of 720 000 lb.; and this, divided by the area of the bearing, gives an average pressure of 28 800 lb. per sq. in. of that surface, or 4 800 lb. per sq. in. in excess of the tensile stress per square inch in the main body of the eye-bar. The elastic limit of the steel is not given in the paper, but it may be assumed as being not far from the pressure developed within the eye upon the pin at the test-strain quoted. Be this as it may, it is a fact that, with the relative proportions adopted, the intensity of pressure, even upon the most favorable assumption of conditions, is greatest where it should be the least.

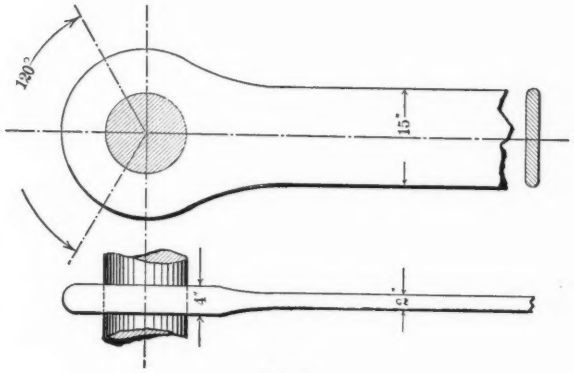



FIG. 9.

The remedy, assuming that the adopted cross-sectional area of the main body of the bar is essential, is to increase the area of the surfaces in contact between the inner surface of the eye and the bearing pin, and, in the writer's opinion, for such a purpose, the extent of this bearing should be approximately twice that of the cross-sectional area of the main body of the bar. This can be obtained in two ways: First, by considerably increasing the diameter of the pin and eye; or, second, by increasing the thickness of the eye. The latter method is regarded as more preferable. Such a construction is shown in Fig. 9, the outside diameter of the eye being decreased and its thickness doubled. The mass of metal is approximately the same in either instance. In this way the effective bearing surface is doubled, that is, it is 50 sq. in.; and, under a loading similar to that cited, the pressure per square inch would be 14 400 lb., or 9 600 lb. per sq. in. less than the tensile stress in the main body of the

Mr. Thomson.

bar and 14 400 lb. per sq. in. less than that in the bar of Fig. 8. In the writer's judgment, this feature is the key to the problem. It may not be quite so "handy" for rolling-mills to slab out bars of the form indicated in Fig. 9, but this would probably be "all to the good," as there appears to be no reason why bars of the dimensions given in the paper should not have their eyes formed by forging, or hydraulic pressure, in forming-dies, as has been done most successfully, in thousands of instances, in the writer's own experience. In this way, too, there is another advantage in that the forged bore of the eye can be swaged, relatively cold, thus condensing and hardening the metal where it bears upon the pin.

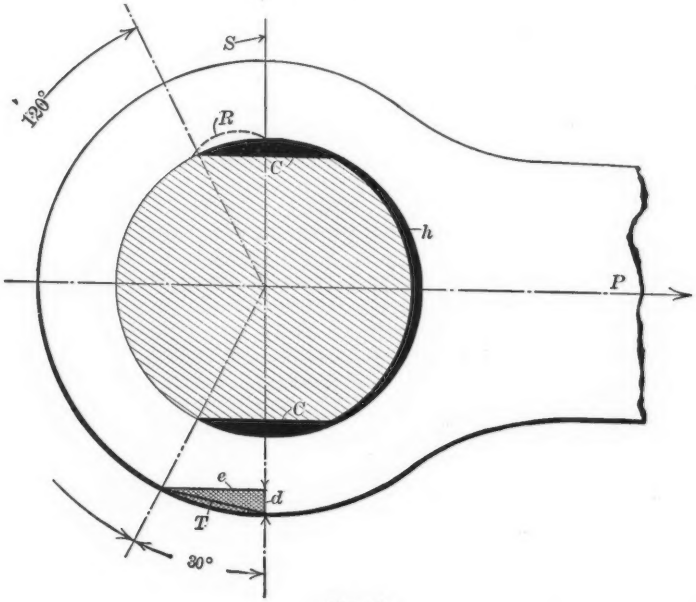



FIG. 10.

There is another point relative to this matter, which, however, is presented with some hesitancy. It is illustrated by Fig. 10. Here, the query is: Would it, or would it not, be advantageous to flatten the pin at the top and bottom, line $S$, at right angles to the line of strain, $P$? As to whether or not this detail is new, the writer does not pretend to say, although he does not know of its having been adopted outside of his own practice. For several years past, this detail has been used especially in bearings, from 12 to 15 in. in diameter and with 2 to 3-in. face, in embossing presses subjected to exceedingly heavy duty. Prior to making this modification, a num-

ber of these rods had failed, having fractured through the forward quadrants of the eyes, where, it may be observed, practically all such fractures take place, at least in the service now being considered. Since making the change in the bearings, that is, planing the flats, *G*, at the top and bottom of the journal or pin, not a single eye has parted, although the duty demanded has since been considerably increased. What is the reason? This the writer does not pretend to answer definitely as the result of actual demonstration, that is, demonstration undertaken for the express purpose of proof, but his theory as to the cause may be stated as follows: Mr. Thomson.

When the eye of the rod is subjected to such a stress that it is stretched away from the free side of the bearing, as *h*, or, what amounts to the same thing, if the forward bearing surfaces wear or yield under compression, this produces motion at the top and bottom of the journal or bearing-pin; and, as a considerable portion of the bearing, in these locations (20°, 30°, 40°), is but slightly effective in resisting strain directly, applied as at *P*, these segments act as highly effective wedges, to augment the direct or normal strain, and operate to burst the forward quadrants of the eye. This so-called "wedge" is denoted, on the lower edge of Fig. 10, on an arc of 30°, in which the bursting effect would be as the relation of the versed sine *d* to the sine *e*; or, say, about five times that of the primary strain, friction being disregarded. Obviously, the same result would be obtained by slightly clearing the eye, as at *R*, or by a less flattening of the pin, as denoted by the line *T*. It may be mentioned that these clearances, in a revolving bearing, afford excellent means for lubrication, and permit a preliminary fit, upon the circular arcs, of the journal or pin, considerably closer than would otherwise be permissible.

Whether the foregoing theoretical explanation stands or falls, the proof of the effectiveness of the principle in practical use, in the application cited, is complete; and the writer would have no hesitation in utilizing it under any analogous condition. In other words, paraphrasing a portion of Mr. Cooper's opening text, "hold fast that which is good," whether or not one finds theories to fit the case. This, however, is not intended to mean that it is not somewhat better to have a close working combination between theory and practice, which is intended to apply especially to Figs. 8 and 9 and the description relative thereto.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## THE PANAMA CANAL.

### Discussion.*

By Messrs. George B. Francis and Theodore Paschke.

Mr. Francis.

George B. Francis, M. Am. Soc. C. E.—Among the arguments in favor of a canal of least first cost, viz., a lock canal, the speaker has not seen any of the following kind, and therefore introduces it as a matter which may be of interest.

No man possesses such a prophetic vision that he can forecast (beyond a very limited number of years) what the future will bring forth. The future tendency, however, can be judged by reasoning from the experience of the past.

In all construction pertaining to transportation by roads, railroads, and canals, a limited number of years has brought about, from various causes, large and important changes. Sometimes routes and construction works have been entirely abandoned. In other cases, the capacity of the work has been many times enlarged. Again, the amount of funds at first available has seemed ridiculously small after traffic had developed to such an extent that adequate construction could be carried out.

At the end of fifty years, the generation then existing has often ridiculed the inadequate conceptions of the original constructors. Knowing from experience the incapacity of mankind to foresee the requirements of the future, beyond a reasonable period, is it wise to

* This discussion (of the paper by A. G. Menocal, M. Am. Soc. C. E., printed in *Proceedings* for February, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for discussion.
Communications on this subject received prior to May 26th, 1906, will be published subsequently.

look too far ahead, or to expend much more money than will produce a reasonable waterway, within a reasonable time, and at reasonable first cost? Mr. Francis.

Is it good judgment to be concerned about the way in which this canal will be altered from a lock to a sea-level canal, in the future, or to spend any money to attain that object?

In the absence of knowledge as to the amount of traffic or the possible alteration and increase in the size and draft of vessels, is it wise to prepare for extremes? On one hand, the lock canal may be adequate for many years; on the other hand, it may be entirely inadequate in a short time.

When the time comes for enlargement, engineers will have new ideas, and, instead of enlarging or lowering the canal in its original location, it may be that a new location, perhaps relatively close to the present one, perhaps as far away as Nicaragua, will be thought more desirable; perhaps two canals, at just such a great distance apart, will be considered better than a larger one in one locality. Perhaps two canals adjoining each other, each taking traffic in one direction only, will be preferred. Even though locks are made so that the canal may be changed to sea-level, the traffic may be so great, when the time to make the change comes, that it will be altogether impracticable, on account of the serious interruption to traffic, or the necessity for temporary abandonment of traffic altogether.

A great number of examples could be cited in support of such conditions, not only in transportation lines, but in public works like fortifications, river improvements, and many minor kinds of construction.

Fifty or one hundred years from now, the wealth and energy of the United States will be beyond the possible conception of any person now living, and the expenditure of $100 000 000, which is a large sum to-day, will seem to be relatively small to the statesman or engineer of the future.

Looking at the whole problem of the Panama Canal from this point of view, is it not good judgment to build now a good, substantial lock canal for substantially the needs within view, or, in the event of a decision to build either a sea-level or a lock canal, to expend no appreciable amount of money thereon in preparation for changes or enlargements which may be remote, and may be made in a manner entirely different from that now conceived?

THEODORE PASCHKE, M. AM. SOC. C. E.—The special feature of Mr. Menocal's paper is an argument in favor of a lock canal, culminating in the somewhat novel proposition of the combined viaduct-dam at Gamboa. Mr. Paschke.

However interesting this feature may be to the lock-canal partisans, it will be well to defer its full consideration until a necessity

Mr. Paschke. therefor has arisen, and until it has been fully decided that a lock canal shall be built. This opportunity is taken to express the hope that that time may never come.

To the speaker, this paper seems to be a very timely invitation to the engineers of the country to express their opinions on the all-important question which at present is before the United States Government for decision; and it behooves this Society to speak freely on the question as to the type of canal which should be adopted.

It is with this in view that the speaker ventures a few remarks on this subject.

Mr. Menocal says:

"It is evident that a lock canal is the most economical type, both in cost and time of construction, and that the sea-level proposition is born * * * of sentiment," etc.

The question of comparative economy between the two types is fully covered, and may best be left to be answered by the testimony given before the Senate Committee by J. F. Wallace, Past-President, Am. Soc. C. E., the late Chief Engineer of the Canal.

As to the matter of the sea-level proposition being born of sentiment, why, the speaker, for one, on the sea-level side, admits this at once, and without hesitation. All achievements in the march of civilization, of improvement, are born of sentiment. Was not the voyage across the Atlantic of that most intrepid of all navigators, Christopher Columbus, which resulted in the discovery of this continent, born of sentiment? And how about the Declaration of Independence? And still later, the preservation of the Union? Were these not born of sentiment? Here is a whole chain of grand, noble sentiments, one after the other, growing out of the primary sentiment entertained by the Genoese ancient mariner, culminating finally in the reasonable expectation of the realization of his dream of more than four hundred years ago. Why, then, should sentiment detract from the sea-level proposition?

The speaker is inclined to remind the author that we are at Panama, not at Nicaragua. If he were at the latter place, he would be justified in sweeping aside the sea-level proposition as born of sentimentality. But, at Panama the sentiment of the sea-level proposition becomes tangible and within the range of practicable execution. Yea, more, the sentiment becomes conviction that the sea-level proposition is the best and the only proposition worthy of consideration.

All will admit that the underlying sentiment of an ideal type for a ship canal across the Isthmus is a free and unobstructed passage of ships, and all, even the most fervent enthusiasts of the lock proposition, will admit that a lock in a ship canal is an obstacle, a hindrance, to such free and unobstructed passage, notwithstanding

the labored paradoxical arguments advanced in the minority report of the consulting engineers. Now, reducing the question of superiority of type to a simple arithmetical proposition, there is the lock-canal proposition with four or more obstacles in the way of a free and unobstructed passage of ships, as against the sea-level proposition with only one lock, and that one open for one-third of the time. There is the underlying sentiment of the sea-level propo- School. Mr. Paschke.

There is no desire on the speaker's part to make light of the engineering difficulties in the way of a realization of the proposition for a sea-level canal, but he has faith in the resourcefulness, in the genius of American engineering talent to solve all problems in connection with the proposition completely and successfully, when confronted with the mandate of the nation.

# MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

## JAMES MacNAUGHTON, M. Am. Soc. C. E.*

DIED DECEMBER 29TH, 1905.

James MacNaughton was born on January 6th, 1851, in Albany, New York, and died on December 29th, 1905, in New York City. He was the son of Dr. James MacNaughton, Dean of the Faculty of the Albany Medical College.

His early education was received at the Albany Boys' Academy, Albany, New York, from which institution he was graduated in 1867. After a year's study, he entered the sophomore class of Yale College, and was graduated with honors from the classical department in July, 1871. While there he paid particular attention to the study of mathematics, and had conferred upon him the second senior mathematical prize of his class.

After graduation he accompanied Professor Marsh as a member of his party on a geological exploration in Kansas, Colorado and Wyoming. On his return to Albany from this expedition he studied chemistry and other scientific branches at the Albany Medical College. In 1873 he entered the Rensselaer Polytechnic Institute, and took a special course in technical engineering subjects for a period of two years.

In 1875, immediately after leaving the Rensselaer Polytechnic Institute, he was appointed Rodman on Mr. C. L. McAlpine's party on surveys for the new aqueduct for New York City. He was engaged in the field, and also on the office work in connection with this survey, and remained with the party until the completion of the maps, estimates, etc., in the fall of the next year.

In April, 1876, he was appointed Rodman in the Department of Public Works, New York City, in connection with the construction of the new storage reservoir near Brewster, New York. Soon after his appointment to this position, he was made Leveler on the same work, and was thus engaged for about a year and a half.

In the autumn of 1877, he was promoted to be an Assistant in charge of the surveys for the location of a new storage reservoir, east of Brewster Station, but in the latter part of December, 1877, he resigned and returned to Albany, where he took charge of superintending and getting out the plans for the Hotel Kenmore, in Albany. He had charge of this work as Superintending Engineer

* Memoir prepared by James C. McGuire, Assoc. M. Am. Soc. C. E.

of construction, and in January, 1879, as soon as the work was completed, he went abroad, and for four months was engaged in study in the École des Ponts et Chaussées, at Paris.

He returned to the United States in October, 1879, and shortly thereafter was engaged as Assistant Engineer on the West Shore Railroad for about two years.

In 1885 he was appointed an engineer on an expedition sent out by the Canadian Government on H. M. S. *Alert,* which made explorations and surveys on the Hudson Bay Coast.

Mr. MacNaughton was a member of the Association for the Preservation of the Adirondacks, and took much interest in the development of the forests and the cutting of timber from large tracts of land. In 1903 he took a course at the Yale Forestry School.

He was elected a Member of the American Institute of Mining Engineers in 1890. The late President Blanco of Venezuela decorated him for services in that country, in connection with certain engineering enterprises. He was a Member of the New York Board of Trade and Transportation of New York City.

Just prior to his death, he did much to develop the manufacture of Ferro-Titanium on a commercial basis, having been President of the Ferro-Titanium Company which built a plant at Niagara Falls and successfully manufactured Ferro-Titanium for the market. He received much recognition for his work in this line, both in the United States and abroad, and it is entirely due to his efforts that the use of this alloy has been made possible from a commercial standpoint. He was also President of the MacIntyre Iron Company at the time of his death.

Mr. MacNaughton was a member of the Arts Club, the University Club, and the Down Town Association, of New York City; the Tahawas Club, of Essex County, New York, the Fort Orange Club, and the Albany Country Club, of Albany, New York.

It is to be particularly noted that both in his business connections, and in the societies and clubs of which he was a member, he was always conspicuous for his dignified bearing and courteous treatment of all who came in contact with him, and especially those under him. He never married.

While his loss to his friends is great, his loss to the scientific world is even greater, for he was engaged in the development of properties and industries of which his knowledge was so complete, and for which he had done so much that it will be impossible to fill his place. His death is mourned by all who knew him or who came in contact with him, either as a friend or as a citizen.

Mr. MacNaughton was elected a Member of the American Society of Civil Engineers on May 5th, 1880.

# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

OF

# CIVIL ENGINEERS.

(INSTITUTED 1852.)

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VOL. XXXII. No. 5.

MAY, 1906.

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Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

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**Society Affairs**.....Pages 167 to 192.
**Papers and Discussions**.....Pages 381 to 438.

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NEW YORK 1906.

Entered according to Act of Congress, by the AMERICAN SOCIETY OF CIVIL ENGINEERS, in the office of the Librarian of Congress, at Washington.

# American Society of Civil Engineers.

## OFFICERS FOR 1906.

*President*, FREDERIC P. STEARNS.

*Vice-Presidents.*

| *Term expires January, 1907:* | *Term expires January, 1908:* |
|---|---|
| M. L. HOLMAN, | ONWARD BATES, |
| E. KUICHLING. | BERNARD R. GREEN. |

*Secretary*, CHARLES WARREN HUNT.

*Treasurer*, JOSEPH M. KNAP.

*Directors.*

| *Term expires January, 1907:* | *Term expires January, 1908:* | *Term expires January, 1909.* |
|---|---|---|
| CHARLES S. GOWEN, | AUSTIN L. BOWMAN, | GEORGE GIBBS, |
| NELSON P. LEWIS, | MORRIS R. SHERRERD, | J. WALDO SMITH, |
| JOHN W. ELLIS, | HEZEKIAH BISSELL, | EMIL SWENSSON, |
| GEORGE S. WEBSTER, | EDWIN A. FISHER, | JAMES M. JOHNSON, |
| RALPH MODJESKI, | WILLIAM B. LANDRETH, | WYNKOOP KIERSTED, |
| CHARLES D. MARX. | GEORGE S. PIERSON. | WILLIAM B. STOREY, JR. |

*Assistant Secretary*, T. J. McMINN.

## Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

| *On Finance:* | *On Publications:* | *On Library:* |
|---|---|---|
| EMIL KUICHLING, | MORRIS R. SHERRERD, | NELSON P. LEWIS, |
| CHARLES S. GOWEN, | J. WALDO SMITH, | AUSTIN L. BOWMAN, |
| GEORGE GIBBS, | ONWARD BATES, | RALPH MODJESKI, |
| M. L. HOLMAN, | BERNARD R. GREEN, | HEZEKIAH BISSELL, |
| GEORGE S. PIERSON. | GEORGE S. WEBSTER. | CHARLES WARREN HUNT. |

## Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON RAIL SECTIONS:—Joseph T. Richards, C. W. Buchholz, E. C. Carter, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

ON CONCRETE AND REINFORCED CONCRETE:—C. C. Schneider, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, J. W. Schaub, Emil Swensson, A. N. Talbot, J. R. Worcester.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER: - - - 533 Columbus.
CABLE ADDRESS: - "Ceas, New York."

Vol. XXXII. MAY, 1906. No. 5.

# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## SOCIETY AFFAIRS.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

**May 2d, 1906.**—The meeting was called to order at 8.35 P. M.; President Frederic P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, 130 members and 24 guests.

The minutes of the meetings of April 4th and 18th, 1906, were approved as printed in the *Proceedings* for April, 1906.

Stacy B. Opdyke, Jr., M. Am. Soc. C. E., moved that the following resolution be referred to the Board of Direction (Art. VI, Sec. 12, of the Constitution):

"*Resolved*, That a Special Committee be appointed to collect such information as may be obtainable on the present and prospective status of the adoption of the metric system in the United States, and to collate and systematize such information and promulgate it to the Society in form of reports from time to time."

The motion, being duly seconded, was adopted by a vote of more than twenty-five Corporate Members.

A paper, by William W. Harts, M. Am. Soc. C. E., entitled "The Control of Hydraulic Mining in California by the Federal Government," illustrated with lantern slides, was read by the Assistant Secretary. The Secretary presented correspondence on the paper from Messrs. H. H. Wadsworth, F. Riffle and J. D. Galloway, and the subject was discussed orally by Richard Lamb, M. Am. Soc. C. E.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Paul Goodwin Brown, New York City.
James Francis Cullen, Havre de Grace, Md.
John Henry Dockweiler, San Francisco, Cal.
Chauncey Eldridge, Boston, Mass.
Norman MacPherson Hench, Pittsburg, Pa.
Horace Longuet Higgins, Manila, Philippine Islands.
Albert Harrison Hogeland, St. Paul, Minn.
Daniel Webster McMorris, Corregidor Island, Philippine Islands.
Charles Fillmore Mebus, Philadelphia, Pa.
Eugene Francis Musson, Norwich, N. Y.
Walter Howard Sawyer, Lewiston, Me.
Charles Herbert Vaughan, New Brighton, Pa.
Luther Wagoner, San Francisco, Cal.

As Associate Members.

Warren Martin Archibald, Nashville, Tenn.
Wilford Willis DeBerard, Harrisburg, Pa.
Louis Harvey Ehrbar, New York City.
Albert Preston Greensfelder, St. Louis, Mo.
Edward Creswell Heald, Washington, D. C.
Oskar Augustus Johannsen, Ithaca, N. Y.
Masayoshi Kabashima, Kansas City, Mo.
George Smith Green Lewis, New York City.
Washington Irving Lex, Pencoyd, Pa.
Herbert Prescott Linnell, Cristobal, Canal Zone, Panama.
Armour Cantrell Polk, New Orleans, La.
Frank Forrest Sinks, Chicago, Ill.
James Bean Wilson, Chicago, Ill.
Joseph Johnson Yates, Elizabeth, N. J.

As Associate.

Robert Hileman Lee, Kingston, R. I.

The Secretary announced:

The transfer of the following candidates, by the Board of Direction, on May 1st, 1906:

FROM ASSOCIATE MEMBER TO MEMBER.

OSCAR FRANCIS BELLOWS, Albany, N. Y.
HOWARD NICHOLAS EAVENSON, Gary, W. Va.
FOSTER HAVEN HILLIARD, Memphis, Tenn.
WILLIAM STONE JOHNSON, Boston, Mass.
FREDERICK THOMAS LLEWELLYN, New York City.
SANFORD ELEAZER THOMPSON, Newton Highlands, Mass.
EDWARD DE VOE TOMPKINS, New York City.

The election of the following candidates by the Board of Direction:

AS JUNIORS.

On April 3d, 1906:

GOUVERNEUR CADWALADER, Philadelphia, Pa.
GEORGE NOBLE COPLEY, Galveston, Tex.
CHESTER CENTENNIAL FISHER, Rupert, Idaho.

On May 1st, 1906:

FREDERICK BAYARD BARSHELL, New York City.
MAX JOHN BARTELL, San Francisco, Cal.
ROY BULLEN, Rupert, Idaho.
LOUIS CHEVALIER, Detroit, Mich.
ELIHU CUNYNGHAM CHURCH, New York City.
FRANK GILLELEN, Los Angeles, Cal.
EDWARD HAROLD HOPSON, Pawling, N. Y.
JOHN MARVIN PETERS, Connellsville, Pa.
FREDERICK HORACE TIBBETTS, San Francisco, Cal.
ADONIRAM JUDSON WARLOW, Wilkes-Barre, Pa.

The Secretary read a letter he had lately received from Otto von Geldern, M. Am. Soc. C. E., Secretary of the Technical Society of the Pacific Coast, stating that the great need of the engineers of San Francisco was drawing instruments, paper, and office supplies. The dealers having been burned out, such articles could not be purchased, and even if they could be secured there was no money to pay for them.

On motion, duly seconded, the Secretary was authorized to expend a sum, not to exceed $1 000, in the purchase of supplies for the prompt relief of the engineers of San Francisco.

The Secretary announced that a circular will soon be issued in regard to the arrangements for the Annual Convention at the Hotel Frontenac, Thousand Islands, on June 26th to 29th, 1906, and that the following topics for informal discussion have been chosen for that meeting:

1.—What is the best Preparatory Education for the Civil Engineering Profession?
2.—Is Technical Training the Best Education for Executive Work?
3.—The Protection of the Intellectual Property of Civil Engineers.
4.—The Advance in Sewage Disposal.
5.—What are the Best Means for the Prevention of Conflagrations in Large Cities?
6.—The Filtration of Water.

Adjourned.

**May 16th, 1906.**—The meeting was called to order at 8.35 P. M.; H. F. Dunham, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 156 members and 64 guests.

A paper, by George B. Francis and W. F. Dennis, Members, Am. Soc. C. E., entitled "The Scranton Tunnel of the Lackawanna and Wyoming Valley Railroad," was presented by Mr. Francis and illustrated with lantern slides.

The paper was discussed by Messrs. F. Lavis, V. H. Hewes and George B. Francis.

The Secretary announced that, in accordance with the action of the Society at its last meeting, he had purchased and forwarded to the Technical Society of the Pacific Coast $500 worth of drafting instruments and office supplies for the engineers who had lost everything in the disaster at San Francisco. He also read letters from members in San Francisco expressing their satisfaction with the action of the Board of Direction in offering to replace any Society publications lost by any member in the fire at very small cost.

The Secretary announced the death of CHARLES LOUIS SPIER, elected Associate May 3d, 1905; died May 7th, 1906.

Adjourned.

## OF THE BOARD OF DIRECTION.

(Abstract.)

**May 1st, 1906.**—President Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bissell, Bowman, Ellis, Gowen, Knap, Kuichling, Lewis, Noble, Schneider, Sherrerd, and Smith.

The Secretary was authorized to send as complete a set of *Transactions* as possible to the Technical Society of the Pacific Coast to replace the files lost by fire.

The Secretary was authorized to furnish to any member who has lost his volumes of *Transactions,* through the San Francisco disaster, duplicates at a discount of 75% from the list price.

The Secretary was directed to communicate with the President of the San Francisco Association of Members of this Society expressing sympathy with our members in San Francisco, and asking in what manner the Society can best aid engineers in that city during the present crisis.

Applications were considered, and other routine business transacted.

Seven Associate Members were transferred to the grade of Member, and ten candidates for Junior were elected.*

Adjourned.

* See page 169.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, June 6th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "Disposal of Municipal Refuse, and Rubbish Incineration," by H. de B. Parsons, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in *Proceedings* for April, 1906.

**Wednesday, September 5th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "Concerning the Investigation of Overloaded Bridges," by Wilbur J. Watson, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in *Proceedings* for April, 1906.

**Wednesday, September 19th, 1906.**—8.30 P. M.—At this meeting a paper, entitled "Street Traffic in New York City, 1885 and 1904," by Clifford Richardson, Assoc. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

### ANNUAL CONVENTION.

The Thirty-eighth Annual Convention of the Society will be held at The Frontenac, Thousand Islands, Frontenac, N. Y., on June 26th to 29th, 1906.

The general arrangements for the Convention are in the hands of the following Committee:

CHARLES S. GOWEN,
JOHN W. ELLIS, MORRIS R. SHERRERD,
J. WALDO SMITH, CHAS. WARREN HUNT.

A Circular in regard to the Convention has already been issued.

## PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 410 Penn Avenue, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner, Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten- Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesbrough, England.

**Civil Engineers' Society of St. Paul,** St. Paul, Minn.

**Koninklijk Instituut van Ingenieurs,** The Hague, The Netherlands.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

# ACCESSIONS TO THE LIBRARY.

From April 9th to May 7th, 1906.

## DONATIONS.*

### THE CONQUEST OF ARID AMERICA.

By William E. Smythe. New and Revised Edition. Cloth, 8 x 5 in., illus., 26 + 360 pp. New York, The Macmillan Company, 1905. $1.50 net.

The preface states that the author has endeavored to show the peculiar environment of the arid region and the influence which it will exert on the civilization of our Western land; the lessons to be learned from the more notable of the early pioneer settlements in Colorado, Utah and California; the natural advantages and present development of the great States and Territories between the Missouri River and the Pacific Ocean; the beginning, progress, and triumph of the National irrigation movement and the work of the corps of young men organized into the United States Reclamation Service.

The book is intended to be of value to the investor, the tourist, the economist, the legislator, the reader of history and travel, and those interested in American resources and institutions generally—but. most of all, the author hopes that it will be of some practical use to men and women who are looking for homes in the West. There is an index of ten pages.

### VENTILATION OF BUILDINGS.

By William G. Snow and Thomas Nolan. Cloth, 6 x 4 in., 83 pp. New York, D. Van Nostrand Company, 1906. 50 cents.

The authors have tried to condense the statement of the general principles of ventilation and of their application to different kinds of buildings. The details of the mechanics of ventilation have been purposely omitted, as they are discussed in another volume of this series. It is hoped that the book may prove useful, not only as a popular presentation of the subject for the general public, but also as a suggestive outline in architectural, engineering and other schools, in connection with or introductory to the whole subject of ventilation. The Contents are divided into three parts: I.—General Principles of Ventilation; II.—Different Systems of Ventilation; III.—Ventilation of Different Kinds of Buildings. There is no index.

### YARDS AND TERMINALS AND THEIR OPERATION.

By J. A. Droege. Cloth, 9 x 6 in., illus., 285 pp. New York, The Railroad Gazette, 1906. $2.50.

The author states that the relative importance of the freight terminals of a line of railroad is not usually understood, and the attention they deserve is not always given them. As improved terminals result in a more prompt and cheaper handling of freight, and tend to a more general utilization of freight lines, many railroads are adding to or remodeling existing yards. The newly constructed or "model" yard is mainly interesting, therefore, in that it affords a guide for the revision, extension or remodeling of the old yards. The first chapter of the book is devoted to the relative importance of terminals and main lines in point of cost of operation and linear feet of rail used, with the terminal problem of Greater New York given as an example. In the second chapter, the author recommends the adoption of the terms and definitions relating to terminals and yards compiled by a committee of the American Railway Engineering and Maintenance of Way Association. In the chapters on the designing of terminals, extracts from the report of the Committee on Yards and Terminals of the same Association are taken as a basis of discussion. Several chapters of the book are devoted to the operation and operating forces of terminals and yards, which may be read with interest by railroad men generally. The instructions as to the rapid handling of fast freight and the construction and location of freight houses and piers are given in two chapters. The book is illustrated with line cuts and half tones. The Contents are: Relative Importance of Terminals; Terms and Definitions; General Principles of Design; Designing Terminals; Track Details; Ash Tracks; Coaling Plants; Icing Plants; Switching Methods; Pole Switching; Summit Switching; Gravity Switching; Records; Management and Discipline; The Yardmaster; Loading Cars; Making Up Trains; Fast Freight; Freight Houses; Freight Piers; and Coal Piers. There is an index of six and one-half pages.

* Unless otherwise specified, books in this list have been donated by the publisher.

Gifts have also been received from the following:

Am. Electrochemical Soc. 1 bound vol.
Am. Locomotive Co. 4 pam.
Am. Soc. of Mech. Engrs. 1 vol.
Am. Steel & Wire Co. 4 pam.
Baltimore, Chesapeake & Atlantic Ry. Co. 2 pam.
Brit. Fire Prevention Committee. 2 pam.
Brooklyn Engrs. Club. 1 bound vol.
Brooklyn Public Library. 1 vol.
Byllesby, H. M., & Co. 1 pam.
Canada-Geol. Survey. 3 pam.
Case School of Applied Sci. 1 vol.
Cay, M. D. 1 drawing.
Cincinnati Southern Ry. Co. 1 bound vol.
Cleveland, Cincinnati, Chicago & St. Louis Ry. Co. 1 pam.
Colo.-Agri. Exper. Station. 5 pam.
Columbus, Ohio-Highway Dept. 1 pam.
Fall River, Mass.-Watuppa Water Board. 1 pam.
Holyoke, Mass.-City Engr. 1 pam.
Illinois Univ.-Agri. Exper. Station. 2 pam.
Incorporated Assoc. of Municipal and County Engrs. 1 bound vol.
India-Public Works Dept. 3 bound vol., 2 vol.
International Assoc. of Municipal Electricians. 1 bound vol.
Jewell Export Filter Co. 1 pam.
Lake Superior Min. Inst. 1 vol.
Luster. W. H. 1 pam.
Mass.-Met. Park Comm. 1 bound vol.
Merchants' Assoc. of San Francisco. 1 pam.
Met. West Side Elev. Ry. Co. 1 pam.
Mexican Inter. R. R. Co. 1 pam.
Missouri-R. R. and Warehouse Commrs. 1 bound vol.
Municipal Engrs. of the City of New York. 1 pam.
New Bedford, Mass.-Water Board. 1 pam.
New Jersey-State Board of Health. 1 bound vol.
New York City-Board of Health. 1 pam.
New York Central & Hudson River R. R. Co. 1 pam.
New York Chamber of Commerce. 1 bound vol.
*New York City Record.* 1 bound vol.
Northampton, Mass.-Board of Water Commrs. 1 pam.
Oberlin College. 1 pam.
Ohio-Board of Health. 1 bound vol.
Pennsylvania R. R. Co. 3 pam.
Pittsburg Filter Mfg. Co. 1 pam.
Pratt Institute Free Library. 1 pam.
Rhode Island-R. R. Commr. 1 bound vol.
Robinson, John. 1 bound vol.
Rose Polytechnic Inst. 1 vol.
St. Louis, Mo.-Board of Public Impvts. 1 pam.
Soc. des Ing. Civils de France. 1 vol.
Stitt, W. T. 27 blue prints.
Thomas S. Clarkson Memorial School of Tech. 1 pam.
Tilden, C. J. 1 pam.
U. S. Bureau of Standards. 1 pam.
U. S. Bureau of Statistics. 1 bound vol.
U. S. Geol. Survey. 5 vol., 2 pam.
U. S. Interstate Commerce Comm. 2 bound vol.
U. S. Isthmian Canal Comm. 1 pam.
U. S. Lake Survey Office. 1 map.
U. S. National Museum. 2 bound vol.
U. S. Senate. 1 pam.
U. S. War Dept. 35 specif.
Univ. of Pennsylvania. 1 pam.
Wallace, J. F. 2 pam.
West Virginia-Geol. Survey. 1 bound vol.
Weston, E. B. 1 pam.
Wilmington, Del.-Park Commrs. 1 pam.
Wyoming-Agri. Exper. Station. 1 pam.

## BY PURCHASE.

**Elektrotechnik in Einzeldarstellungen, Vols. 6-7.** Herausgegeben von G. Benischke. Braunschweig, Friedrich Vieweg und Sohn, 1905.

**Reports. Permanent International Association of Navigation Congresses.** 21 pam. Brussels Printing Office of Public Works (Co. Ltd.), 1905.

**The Nile in 1904.** By William Willcocks. London, E. & F. N. Spon, Limited; New York, Spon & Chamberlain, 1904.

**National Engineering and Trade Lectures, Vol. II.** British Progress in Pumps and Pumping Engines. By Philip R. Björling. London, Archibald Constable & Co., Ltd., 1905.

**National Engineering and Trade Lectures, Vol. III.** British Progress in Gas Works' Plant and Machinery. By C. E. Brackenbury. London, Archibald Constable & Co., Ltd., 1905.

**The Prevention of Senility and a Sanitary Outlook.** By Sir James Crichton-Browne. London, Macmillan & Co., Limited; New York, The Macmillan Company, 1905.

**A Text-Book on Gas, Oil, and Air Engines.** By Bryan Donkin. Fourth Edition, Revised and Enlarged. London, Charles Griffin and Company, Limited, 1905.

**Gasworks Accounts and Management.** By George Helps. London, The *Gas World* Offices, 1905.

**Hydraulique Agricole et Urbaine.** Par G. Bechmann. Paris, Ch. Béranger, 1905.

**Alternating Currents,** Their Theory, Generation and Transformation. By Alfred Hay. New York, D. Van Nostrand Company, 1906.

**Metallurgical Calculations.** By Joseph W. Richards. New York, McGraw Publishing Company, 1906.

## SUMMARY OF ACCESSIONS.

From April 9th to May 7th, 1906.

| | |
|---|---|
| Donations (including 5 duplicates and one number completing volume of periodical) | 164 |
| By purchase | 32 |
| Total | 196 |

## MEMBERSHIP.

### ADDITIONS.

#### MEMBERS.

| | | Date of Membership. |
|---|---|---|
| BELLOWS, OSCAR FRANCIS. Asst. Engr., N. Y. State Barge Canal, Barge Canal Office, DeGraff Bldg., Albany, N. Y. | Assoc. M. | Dec. 4, 1901 |
| | M. | May 1, 1906 |
| BROWN, PAUL GOODWIN. 461 Lexington Ave., New York City | | May 2, 1906 |
| EAVENSON, HOWARD NICHOLAS. Chf. Engr., United States Coal & Coke Co., Gary, McDowell Co., W. Va | Assoc. M. | Mar. 6, 1901 |
| | M. | May 1, 1906 |
| FROSELL, CARL GUSTAF. Engr., Am. Bridge Co., Pencoyd, Pa. | | April 4, 1906 |
| HARING, ALEXANDER. 2305 Loring Pl., University Heights, New York City | | April 4, 1906 |
| HUGGINS, WILLIAM. Care, Wm. Krug & Son, 42 Rua S. Bento, Sao Paulo, Brazil | | Feb. 7, 1906 |
| JOHNSON, WILLIAM STONE. Asst. Engr., State Board of Health, Room 140, State House, Boston, Mass. | Assoc. M. | June 6, 1894 |
| | M. | May 1, 1906 |
| LUIGGI, LUIGI. 81 Via Vardegna, Rome, Italy | | Feb. 7, 1906 |
| MENDEN, WILLIAM STEPHEN. 752 Westminster Rd. (Flatbush), Brooklyn, N. Y. | | April 4, 1906 |
| OLIVER, EMERY. Div. Engr., West. Pac. Ry. Co., Oroville, Cal. | | Mar. 7, 1906 |
| ROSS, ELMER WAYLAND. Asst. Engr., Bridge Dept., City Engr.'s Office, Providence, R. I. | Jun. | Mar. 5, 1890 |
| | Assoc. M. | June 1, 1892 |
| | M. | April 3, 1906 |
| SELTZER, HARRY KENT. Res. Engr., Waddell & Hedrick, I. & G. N. R. R., Bridge Reconstruction, Austin, Tex. | Jun. | Feb. 4, 1896 |
| | Assoc. M. | Jan. 2, 1901 |
| | M. | April 3, 1906 |
| SHAW, ENOS LARKIN. 2667 N. Ashland Ave., Chicago, Ill. | Jun. | Oct. 3, 1893 |
| | Assoc. M. | June 1, 1898 |
| | M. | Mar. 6, 1906 |
| SMITH, WALTER MICKLE. Const. Engr., Ordnance Dept., U. S. A., Dover, N. J. | Assoc. M. | Oct. 2, 1901 |
| | M. | April 3, 1906 |
| THOMPSON, SANFORD ELEAZER. Cons. Engr., Newton Highlands, Mass. | Assoc. M. | April 1, 1896 |
| | M. | May 1, 1906 |
| TOMPKINS, EDWARD DE VOE. Cons. Engr. and Mgr., New York Office, Maine Elec. Co., 1 Madison Ave., New York City (Res., 372 Park Pl., Brooklyn, N. Y.) | Jun. | Feb. 2, 1897 |
| | Assoc. M. | Dec. 3, 1902 |
| | M. | May 1, 1906 |
| WARD, THOMAS MONROE. Care, Canton Co., 15 South St., Baltimore, Md. | | Mar. 7, 1906 |

ASSOCIATE MEMBERS.

| | Date of Membership. |
|---|---|
| ALLEN, JOHN LEE. Dist. Mgr., Genasco Roofing Co., 1139 Stock Exchange Bldg., Chicago, Ill | Nov. 1, 1905 |
| BARTON, CALVIN LEWIS. 159 Madison Ave., New York City | April 4, 1906 |
| BOOZ, HORACE COREY. 663 Broad St. Station, Philadelphia, Pa. | April 4, 1906 |
| CLAPP, WILFRED ATHERTON. 103 Sherman St., Portland, Me. | April 4, 1906 |
| GARDINER, JOHN PEDEN. Engr., Guadalupe Mine, Inde, Dgo., Mexico | Mar. 7, 1906 |
| HEALD, EDWARD CRESWELL. Chf. Structural Engr., Office of Superv. Archt., Treasury Dept., 1720 N St., Washington, D. C. — Jun. | Oct. 7, 1902 |
| HEALD, EDWARD CRESWELL. Chf. Structural Engr., Office of Superv. Archt., Treasury Dept., 1720 N St., Washington, D. C. — Assoc. M. | May 2, 1906 |
| HENDERSON, ADELBERT ANDREW. 730 Franklin Ave., Wilkinsburg, Pa. | April 4, 1906 |
| JEWEL, LINDSEY LOUIN. 504 Jeannette St., Wilkinsburg, Pa. | April 4, 1906 |
| JUDELL, ADOLPH. Chf. Engr., Nevada Northern Ry., Toana, Nev. | April 4, 1906 |
| KOLB, HENRY JACOB. Chf. Draftsman, Office of Chf. Engr., Brooklyn Rapid Transit System, 85 Clinton St., Brooklyn, N. Y. — Jun. | Feb. 3, 1903 |
| KOLB, HENRY JACOB. Chf. Draftsman, Office of Chf. Engr., Brooklyn Rapid Transit System, 85 Clinton St., Brooklyn, N. Y. — Assoc. M. | April 4, 1906 |
| LOVELL, EARL BRINK. 235 West 102d St., New York City. | April 4, 1906 |
| PAWLING, GEORGE FRANKLIN. 1622 Real Estate Trust Bldg., Philadelphia, Pa. | April 4, 1906 |
| PRENTICE, WILLIAM HENDRY, Jr. Asst. Engr., M. O. & G. R. R., Muskogee, Ind. T. | April 4, 1906 |
| PRIEST, BENSON BULKELEY. Care, Am. Bridge Co., 42 Broadway, New York City. | April 4, 1906 |
| SANFORD, GEORGE OTIS. Asst. Engr., U. S. Reclamation Service, Williston, N. Dak. | Mar. 7, 1906 |
| SINKS, FRANK FORREST. Vice-Pres., Condron & Sinks Co., 1442 The Monadnock, Chicago, Ill. | May 2, 1906 |
| SMITH, CHARLES BAILEY. 1405 State St., Boise, Idaho. | Jan. 3, 1906 |
| TURNER, HENRY CHANDLEE. 11 Broadway, New York City. | April 4, 1906 |
| WAGNER, FRED J. Asst. Engr., Dept. of N. Y. State Engr., Sylvan Beach, Oneida Co., N. Y. | April 4, 1906 |
| WILHELM, JEROME FREDERICK. Asst. Engr., Mo. Pac. Ry., Lock Box 181, Paragould, Ark. — Jun. | Jan. 2, 1900 |
| WILHELM, JEROME FREDERICK. Asst. Engr., Mo. Pac. Ry., Lock Box 181, Paragould, Ark. — Assoc. M. | Mar. 7, 1906 |
| WOOD, GEORGE ROY. Cons. Elec. Engr., Fulton Bldg., Pittsburg, Pa. | April 4, 1906 |
| YATES, JOSEPH JOHNSON. 941½ South St., Elizabeth, N. J. | May 2, 1906 |

JUNIORS.

| | Date of Membership. |
|---|---|
| CALDWELL, FRED EDWARD. Newton, N. J. | April 3, 1906 |
| CHURCH, ELIHU CUNYNGHAM. 4 East 130th St., New York City. | May 1, 1906 |
| COPLEY, GEORGE NOBLE. 306 Trust Bldg., Galveston, Tex. | April 3, 1906 |
| CROW, EDWARD. Harbour Board Office, Lyttelton, New Zealand | Oct. 3, 1905 |
| DAY, WILLIAM PEYTON. 144 Sanchez St., San Francisco, Cal. | Mar. 6, 1906 |
| FISHER, CHESTER CENTENNIAL. U. S. Reclamation Service, Rupert, Idaho | April 3, 1906 |
| FRYER, HENRY LE ROY. Aleda Apartments, Trenton, N. J. | April 3, 1906 |
| GIBBS, ELBERT ALLAN. 302 Mitchell St., Ithaca, N. Y. | Mar. 6, 1906 |
| HUBER, WALTER LEROY. 2120 Kittredge St., Berkeley, Cal. | April 3, 1906 |
| SHIPMAN, CHARLEY EVANS. Care, U. S. Reclamation Service, Billings, Mont. | April 3, 1906 |
| SOULÉ, EDWARD LEE. 608 Crossley Bldg., San Francisco, Cal. | April 3, 1906 |

## DEATHS.

SPIER, CHARLES LOUIS. Elected Associate, May 3d, 1905; died May 7th, 1906.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(April 8th to May 5th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*. New York City. Issues for first Saturday of each month 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefeuille Economique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.

(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Street Railway Review*, Chicago, 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.

## LIST OF ARTICLES.

### Bridge.

Bridges. Willis Whited. (58) Apr.
A Flat Span Reinforced Concrete Bridge at Memphis.* (14) Apr. 7.
Rebuilding the Rondout Viaduct.* (14) Apr. 7.
The Distribution of Loads on Stringers of Highway Bridges Carrying Electric Cars. F. P. McKibben, M. Am. Soc. C. E. (13) Apr. 12.
Reinforced Concrete Bridges on the Chicago & Eastern Illinois.* (15) Apr. 13.
Curves for Reinforced Arches. Daniel B. Luten. (14) Apr. 14.
Steel Piling Cofferdams for Bridge Piers.* (14) Apr. 21.
The Pennsylvania Railroad Bridge at Havre de Grace.* (14) Apr. 28.
The Surface Finish of Concrete Bridge Masonry.* George S. Webster. (14) Apr. 28.
A "Double-Drum" Reinforced Concrete Arch Highway Bridge.* Daniel B. Luten. (13) May 3.
Die Illerbrücken bei Kempten im Allgäu.* D. Colberg. (From a Paper read before the Deutscher Beton Verein.) (51) Serial beginning Apr. 21.

### Electrical.

Some Notes on Wires. Thomas Carter. (26) Mar. 30.
Recent Extensions at the Manchester Electricity Works.* (73) Serial beginning Mar. 30.
Portable Electric Tools and Their Industrial Application. Andrew Stewart. (73) Mar. 30.
Standardizing Rubber-Covered Wires and Cables. John Langan. (42) Apr.
Comments on Present Underground Cable Practice. Wallace S. Clark. (42) Apr.
Notes on Design of Hydro-electric Power Stations (With Reference to the Influence of Load Factor).* David B. Rushmore. (42) Apr.
The Relation of Load-Factor to the Evaluation of Hydro-electric Plants. S. B. Storer. (42) Apr.
Electric Motors for Driving Machine Tools. (21) Serial beginning Apr.
The Pennsylvania Railroad's Extension to New York and Long Island: Some Details of the Long Island City Power Station.* (14) Apr. 7; (40) Apr. 6; (18) serial beginning Apr. 14; (72) Apr.; (25) May.
The Nassau (L. I.) Light and Power Company.* (27) Apr. 7.
The Wiring and Maintenance of Shunt and Compound-Wound Motors. William Kavanagh. (27) Apr. 7.
An Example of House Lighting Design.* J. R. Cravath and V. R. Lansingh. (27) Apr. 7.
A Portable Selenium Photometer for Incandescent Lamps.* Theo. Torda. (73) Apr. 13.

* Illustrated.

**Electrical—(Continued).**

Electrical Equipment of Wanamaker's Philadelphia Store.* (27) Apr. 14.
The New Lighting and Power Station at Glenwood.* (14) Apr. 14.
Rates for Electric Current in Chicago. (Report to the Chicago City Council by B. J. Arnold and Wm. Carroll.) (14) Apr. 14.
Method of Design for Magnet Windings. F. Albert Willard. (27) Apr. 21.
Hydro-Electric Development in the Adirondacks.* (27) Apr. 21.
Speed Characteristics and the Control of Electric Motors.* Charles F. Scott. (9) May.
Installation and Maintenance of a Small Electric Light Plant.* (64) May.
Usine Elévatoire de Messein pour l'Alimentation de la Ville de Nancy en Eau Filtrée.* Mauduit. (33) Mar. 31.
Der Blitzschutz von Eisenbetonbauten. A. Kleinlogel. (78) Apr.
Vereinigte Schaltung und Bedienung von Betriebsmaschinen in Elektrischen Zentralen.* Karl Wertenson. (48) Apr. 14.

**Marine.**

On Vessels Constructed for Service in Our Colonies and Protectorates.* *Sir* Edward J. Reed. (Paper read before the Inst. of Naval Archts.) (11) Apr. 6.
Gas Engines for Ship-Propulsion.* J. E. Thornycroft. (Paper read before the Inst. of Naval Archts.) (11) Apr. 13; (12) Apr. 20.
The Overhead Wire Cableway applied to Shipbuilding. J. L. Twaddell. (Paper read before the Inst. of Naval Archts.) (11) Apr. 13; (22) Apr. 13.
The Introduction of Cranes in Shipyards.* Alexander Murray. (Paper read before the Inst. of Naval Archts.) (11) Apr. 13; (47) Apr. 14.
The Efficiency of Surface Condensers. R. L. Weighton. (Paper read before the Inst. of Naval Archts.) (11) Serial beginning Apr. 13.
French Armoured Cruiser *Ernest Renan.* (12) Apr. 20.
High-Speed Motor-Boats.* James A. Smith. (Paper read before the Inst. of Naval Archts.) (11) Apr. 20.
Le Paquebot *La Provence* de la Compagnie Générale Transatlantique.* A. Dumas. (33) Serial beginning Apr. 7.
Die Turmdeckdampfer *Queda* und *Wellington.** W. Kaemmerer. (48) Mar. 31.

**Mechanical.**

Cement and Hydraulic Limes, Manufacture, Properties and Use.* E. Candlot. (67) Serial beginning Mar.
Coal Conservation, Power Transmission and Smoke Prevention. Arthur J. Martin, M. Inst. C. E. (29) Mar. 30.
An Improved Briquette-Making Machine.* (12) Mar. 30.
Endless Wire-Rope Drives. William Hewitt. (8) Apr.
Test of De Laval Steam-Turbine.* (8) Apr.
Applications of Gas Engineering to the Brick Industry. S. S. Wyer. (76) Serial beginning Apr.
The Pennsylvania Railroad's Extension to New York and Long Island: Some Details of the Long Island City Power Station.* (14) Apr. 7; (40) Apr. 6; (18) serial beginning Apr. 14; (72) Apr.; (25) May.
The New Kiln Firing Process at the Lawrence Cement Co.'s Siegfried Mill.* (14) Apr. 7.
Vertical Retort Settings. E. Körting. (Abstract translation of paper read before the Brandenburg Assoc. of Gas and Water Engrs.) (66) Apr. 10; (83) May 1.
Water-Gas Plant at Trieste.* (66) Apr. 10.
Allis-Chalmers Extensions: Additions to the West Allis Works, Milwaukee, Wis.* (20) Apr. 12.
A High-Pressure Gas Distribution System.* (13) Apr. 12.
Gas Making in Vertical Retorts.* (12) Apr. 13.
Steam Consumption of Winding Engines. (12) Apr. 13.
The Present and Future of Power Gas Plants.* (Paper read before the Eng. and Sci. Assoc. of Ireland.) (66) Apr. 17.
Briquetting of Fuels and Minerals: Description of the Zwoyer Fuel Company's Process and the New Jersey Briquetting Company's Plant.* G. J. Mashek. (20) Apr. 19.
The Prevention of Smoke. Albert A. Cary. (14) Apr. 21.
The New Mechanical Equipment at the Joseph Campbell Factory, Camden, N. J.* (14) Apr. 21.
The Mechanical Plant of the Ford Memorial Building, Boston.* (14) Apr. 28.
8e Exposition Internationale de l'Automobile du Cycle et des Sports.* (36) Serial beginning Dec. 25.
Les Turbines a Gaz.* L. Sekutowicz. (32) Feb.
Généralités sur les Moteurs et Spécialement les Turbines a Gaz.* J. Deschamps. (32) Feb.
Essais du Foyer et de la Chaudière Marcel Deprez et Verney.* L. Lecornu. (37) Mar.

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* Illustrated.

**Mechanical—(Continued).**

Verbesserungen im Dampfkesselbetrieb durch Vermehrten Wasserumlauf.* (82) Feb. 24.
Die Heissluftmaschine mit Grosser Kompression. R. Wotruba. (82) Mar. 31.
Die Herstellung von Hydraulischem Kalk in Frankreich.* (80) Mar. 31.
Der Generator in der Zementindustrie.* C. Naske. (48) Apr. 7.
Ueber die Formänderung von Drahtseilen.* Hirschland. (82) Serial beginning Apr. 7.
Antriebsarten von Walzenstrassen. Franz Gerkrath. (Paper read before the Südwestdeutsch-Luxemburgische Eisenhütte.) (50) Serial beginning Apr. 15.

**Metallurgical.**

New Developments in Dry Air Blast.* A. Steinbart. (Paper read before the Technische Verein.) (22) Mar. 30.
Smelting Iron Ore by Electricity. Eugene Haanel. (Address before the Canadian Club of Toronto.) (62) Apr. 26.
The Lungwitz Process of Zinc Smelting. Fred W. Gordon. (16) Serial beginning Apr. 28.
Schwebetransporte in Berg- und Hüttenbetrieben.* G. Dieterich. (50) Serial beginning Apr. 1.
Ueber die Konstitution des Roheisens.* P. Goerens. (50) Apr. 1.
Die Berechnung des Hochofenprofils und Ihre Grundlegenden Werte.* Bernhard Osann. (Paper read before the Südwestdeutsch-Luxemburgische Eisenhütte.) (50) Apr. 15.

**Military.**

The Pressure of Explosions. J. E. Petavel. (Abstracted from the Philosophical Transactions of the Royal Society of London.) (11) Mar. 30.

**Mining.**

Over-winding in Hoisting Operations.* Robert Peele. (6) Jan.
The Pressure of Explosions. J. E. Petavel. (Abstracted from the Philosophical Transactions of the Royal Society of London.) (11) Mar. 30.
Deep Level Shafts on the Rand.* Arthur E. Pettit. (Paper read before the Inst. of Mining and Metallurgy.) (45) Serial beginning Apr.
Air Hammer Rock Drills: A new Type of Drill for Mining Work. E. A. Rix. (45) Apr.
Head-Frames: Some Notes on the Principles of Construction. W. R. Crane. (45) Apr.
Steam Consumption of Winding Engines. (12) Apr. 13.
Sinking and Tubbing at the Methley Junction Colliery. Isaac Hodges. (Paper read before the Midland Counties Inst. of Engrs.) (57) Apr. 20.
The Application of Direct Cementation in Shaft-Sinking. C. Dinoire. (Abstract of paper read before the Société de l'Industrie Minérale.) (68) Apr. 21.
Hydraulic Dredging.* F. Danvers Power. (16) Apr. 21.
The Honigmann Method of Shaft Sinking.* Adolf E. Hartmann. (16) Apr. 21.
Schwebetransporte in Berg- und Hüttenbetrieben.* G. Dieterich. (50) Serial beginning Apr. 1.

**Miscellaneous.**

The Commercial Organisation of Engineering Factories. Henry Spencer. (12) Serial beginning Mar. 30.
Classification of Engineering Expenditures. F. H. Newell. (14) Apr. 28.
The Metric System Fallacy. (10) May.
The Proposal to Force the Use of the Metric System. H. H. Suplee. (9) May.

**Municipal.**

The Cost of Brick Pavement in Helena, Mont. Charles W. Helmick. (14) Apr. 7.
Vitrified Brick for Paving Purposes. (14) Apr. 14.
Ueber den Griechischen Asphalt und Seine Technische Bedeutung.* A. Ch. Vournasos. (82) Mar. 31.

**Railroad.**

Alternating Current Electric Systems for Heavy Railway Service.* B. G. Lamme. (65) Mar.
The Latest Great Northern Engines. Charles Rous-Marten. (12) Serial beginning Mar. 30.
New Atlantic-Type Locomotives: London, Brighton, and South Coast Railway.* (47) Mar. 31.
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The Work of Well-Drilling Machines on the Pennsylvania R. R. Low-Grade Freight Line. W. R. Hulbert. (13) Apr. 12.
Mallet Compound Duplex Locomotives for the Guayaquil & Quito Railway. (13) Apr. 12.
Reinforced Concrete Work at the New Railway Terminal Station at Atlanta, Ga.* (13) Apr. 12.
New Shops of the Missouri, Kansas & Texas Railway, Parsons, Kansas.* (40) Apr. 13.
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Effects of a Sleet Storm on Different Types of Third Rail Protection.* (15) Apr. 13.
Electric Locomotive for the New York, New Haven & Hartford Railroad.* (27) Apr. 14; (17) Apr. 14.
The Watseka Coal, Ash and Water Plant of the Chicago & Eastern Illinois R. R.* (14) Apr. 14.
First Swedish Superheater Locomotive.* Alfred Gradenwitz. (40) Apr. 20.
Electric Traction for Trunk Lines. (15) Serial beginning Apr. 20.
Line and Surface. Moses Burpee. (18) Serial beginning Apr. 21.
The Alaska Central Railway.* M. S. Duffield. (16) Apr. 21.
Wabash Eastern Improvements.* (15) Apr. 27.
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Motor and Trailer Trucks for the New York Central Electric Service.* (25) May.
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Difficult Reinforced Concrete Retaining Wall Construction on the Great Northern Railway.* C. F. Graff. (13) May 3.
New Tie and Timber Preserving Plant of the Atchison, Topeka & Santa Fe Ry. at Somerville, Texas.* (13) May 3.
Le Chemin de Fer Metropolitain de Paris.* J. Hervieu. (35) Serial beginning Apr.
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Note a Propos du Tunnel sous la Manche.* Albert Sartiaux. (38) Apr.
Note sur les Applications de l'Electricité a l'Exploitation des Chemins de Fer aux Etats Unis. F. Paul-Dubois. (38) Apr.
Note sur les Nouvelles Voitures Automotrices à Vapeur de la Compagnie d'Orléans.* Louis Huet. (38) Apr.
Die Reibungs- und Zahnstangenbahn von Ilmenau nach Schleusingen.* Urbach. (49) Vol. 4-6, 1906.
Motorlokomotiven.* Kramer. (48) Apr. 7.
Neuere Deutsche Schnellzuglokomotiven.* M. Richter. (48) Serial beginning Apr. 14.

**Railroad, Street.**

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Good Wiring Practice on Cars at Washington, D. C.* (17) Apr. 21.
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Traversée sous la Seine du Métropolitain de Paris.* (78) Apr.
Eine Neue Anwendungsform der Eisenbetonbauweise als Gleisbettung für Strassenbahnen.* E. Reinhardt. (51) Serial beginning Apr. 4.
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**Sanitary.**

Sewer Pipe: Its Properties and Requirements. Arthur N. Talbot and Roy H. Slocum. (76) Mar.
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Levee and Drainage Works at Memphis.* (14) Apr. 21.
Heating and Ventilating St. Paul's Hospital, Montreal.* (14) Apr. 21.

* Illustrated.

**Structural.**

Cement and Hydraulic Limes, Manufacture, Properties and Use.* E. Candlot. (67) Serial beginning Mar.
Strength of Mild and Cast Steels at High Temperatures.* (11) Mar. 30.
Erection Methods for Structural Steel: A Topical Discussion. (58) Apr.
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The Farwell, Ozmun & Kirk Co. Warehouse at St. Paul.* W. H. Dillon. (14) Apr. 21.
Concrete Aggregates. Sanford E. Thompson, M. Am. Soc. C. E. (Paper read before the Cement Users' Assoc.) (19) Apr. 21.
Fire-Resisting Construction and the Ultimate Life of Mercantile Buildings: A Plea for Better Construction Methods. J. K. Freitag, Assoc. M. Am. Soc. C. E. (13) Apr. 26.
The Steel Foundations of the Title Guarantee & Trust Co. Building, New York.* (14) Apr. 28.
The Proper Legal Requirements for the Use of Cement Constructions. Rudolph P. Miller. (Read before the Concrete Assoc. and the National Assoc. of Cement Users.) (14) Apr. 28.
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Some Tests Bearing on the Design of Tension Members. Edward Godfrey. (13) May 3.
The Selection of Portland Cement for Concrete Blocks. Richard K. Meade. (Paper read before the Cement Users' Assoc.) (19) May 5.
Analyse Chimique des Chaux et des Ciments. J. Malette. (36) Dec. 10.
Emploi des Cartons Plissés Imperméables dans la Construction.* G. Loucheux. (36) Dec. 10.
Calcul des Hourdis en Béton Armé. P. Caufourier. (33) Apr. 7.
Einige Allgemeine Elastische Werte für den Kreisbogenträger. Adolf Francke. (81) Vol. 1, 1906.
Die Neue Hauptmarkthalle in Köln.* B. Schilling. (49) Vol. 4-6, 1906.
Versuche über die Drehungsfestigkeit von Körpern mit Trapezförmigem und Dreieckigem Querschnitt.* C. Bach. (48) Mar. 31.
Der Wettbewerb des Eisenbetons mit dem Reinen Eisenbau. F. v. E. (78) Apr.
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Der Bau des Lateralkanales von Wranan nach Horin.* W. Rubin. (53) Mar. 30.
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* Illustrated.

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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## STREET TRAFFIC IN NEW YORK CITY, 1885 AND 1904.

By Clifford Richardson, Assoc. Am. Soc. C. E.

To be Presented September 19th, 1906.

In December, 1885, Francis V. Greene, M. Am. Soc. C. E., read a paper before this Society, entitled "An Account of Some Observations of Street Traffic,"* in which he presented certain data, in regard to ten of the large cities of the United States, collected in that year by the employees of the Barber Asphalt Paving Company. He also called attention to the desirability of having traffic measured systematically at frequent intervals, on a uniform system, in the leading cities of the world, for comparative purposes. Since that date no further observations have been made, as far as the writer is aware, in any of the cities considered by Captain Greene, either in the United States or abroad, with the exception of a count, made in 1896, of the number of vehicles traversing Fifth Avenue, New York City, at various points, before the removal of the granite block pavement from that street.

In November and December, 1904, additional data were collected, at the writer's suggestion, by employees of the Barber Asphalt Paving Company, on ten streets in New York City, for the purpose of determining the traffic carried by a number of representative streets at that time. The results of this count, as worked out by

* *Transactions*, Am. Soc. C. E., Vol. XV, p. 123.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

employees of the company, were presented not long after in the engineering journals in comparison with the data of 1885, and with data for Paris and London cited by Captain Greene. The weights attributed to the vehicles, by those working up these data, were made to include the horse or horses, but this was not done in calculating the tonnage in Captain Greene's paper, and has not been the practice abroad. It seems, therefore, that the comparisons made at that time were not correct. All the data having since then come into the writer's possession, it has seemed worth while to present them here, in considerable detail, for future reference, and to compare the results derived from them with those obtained by Captain Greene, when calculated on the basis used by him in 1885, although they have also been worked out on a basis which, it is believed, represents more accurately the traffic carried by the streets in 1904. The data were collected with somewhat greater detail in 1904 than in 1885, as is shown in Table 1.

The observations were made by two persons, an observer and a recorder with a talley sheet. They were taken on two days (with the exception of those on Fifth Avenue, which occupied three days), from windows overlooking the various streets. They covered a period of eleven hours, from 7 A. M. to 6 P. M., being that time of day in which the principal traffic is concentrated, or one hour less than that covered in 1885.

For the purpose of determining the tonnage carried by the various streets, the writer has assigned the following weights to the different classes of vehicles, from data furnished by several of the most prominent carriage and truck builders.

| Vehicle. | Weight. |
|---|---|
| Cab | 1 050 lb. |
| Carriage | 1 575 " |
| Automobile, electric | 4 000 " |
| Automobile, gasoline | 2 325 " |
| Electric truck | 5 000 " |
| One-horse delivery wagon | 1 000 " |
| Two-horse delivery wagon | 1 500 " |
| Omnibus (Fifth Ave.) | 3 200 " |
| Omnibus (streets other than Fifth Ave.) | 1 550 " |
| Trucks, 1 to 8 tons | 2 000 to 16 000 " |

On this basis, the total tonnage per foot of width of street has been calculated, excluding the width of car tracks, where these exist, because the main traffic, especially on asphalt, is confined to that portion of the street lying between the tracks and the curb. This information is given in Table 2.

From the observations of 1885, Captain Greene divided the traffic into only three classes: light weight (less than 1 ton); medium weight (between 1 and 3 tons); and heavy weight (more than 3 tons). For the purpose of comparison with the data of 1885, the observations of 1904 have also been calculated on this basis, using, however, more detailed data in regard to vehicles which weigh more than 3 tons, as those of 6 and 7 tons are not uncommon now in the streets of New York. The results obtained in this way are presented in Table 3.

Having the preceding data, a comparison of the traffic of 1885 with that of 1904 can be made satisfactorily only on Fifth Avenue, the other points of observation in the two years not being the same. This comparison is given in Table 4.

It appears that on Fifth Avenue, 5 460 vehicles passed the Worth Monument in 1885, and 6 300 passed over the granite pavement in 1896; whereas, in 1904, 12 068 were observed between Thirty-third and Thirty-fourth Streets, an increase of about 120 per cent. In 1885 Captain Greene estimated the average weight per vehicle as 0.68 ton. In 1904, according to the weights which have been assumed as correct, the average weight per vehicle was 0.82 ton, or 0.83 ton on Captain Greene's basis. In 1885, 91% of the vehicles weighed less than 1 ton, while, in 1904, 79%, a much smaller number, were of this character. The traffic on this street, therefore, while still composed largely of light vehicles, has increased to an enormous extent in eight years, and the average weight per vehicle to a very considerable extent. The tonnage per foot of width, on Captain Greene's basis of weight, has increased from 94 to 251, or to 247 on the writer's basis.

Reference to Table 2 shows that, with the exception of First Avenue, at Twenty-sixth Street, Fifth Avenue carries the heaviest traffic in the City of New York, although this traffic is composed of the largest percentage of light-weight vehicles. This fact, however, must be given a great deal of consideration, since a small

tonnage of heavy-weight vehicles will undoubtedly cause a greater deterioration of the pavement than a larger traffic of lighter ones.

In 1885 the traffic on Broadway, near Pine Street, amounted to 273 tons per ft. of width. No enumeration was made at this point in 1904, but at the two points where the count was made, between Eighteenth and Nineteenth Streets, on asphalt, and between Franklin and Leonard Streets, on granite block, the tonnage only reached 107.2 in the one case, and 65.5 in the other. These figures are on the Greene basis of calculation, which includes the car tracks in the width of the street, and which must be used for a comparison of 1885 and 1904 data. On the writer's basis of calculation, the tonnage at these two points amounts to 169.8 and 96.9.

These figures are exceeded by those for First, Fifth and Eighth Avenues, and for Fourth Street. It is quite surprising, therefore, to find that the Broadway traffic is not a heavy one, at the present time, as compared with that of several other streets in New York, while it has, very possibly, decreased rather than increased since 1885.

It is an interesting fact that the heaviest traffic which has been counted in New York is on First Avenue, at Twenty-sixth Street, and that it is largely made up of vehicles of a heavy class, averaging 2.18 tons in weight, only 26% being of less than 1 ton. It is also worthy of note that the pavement on this street is not of a form of construction calculated to withstand such a traffic, as it is not supported by a hydraulic concrete base.

For the purpose of comparing the traffic on the streets of New York with that upon streets in London and Liverpool, it seems worth while to present here certain data in regard to the latter, collected by Captain Greene, from the papers of Messrs. Hayward, Deacon, Howarth and Stayton. This information is given in Table 6.

It appears that the tonnage per foot run on some streets in London was far greater, even in 1873, than anything found in New York, reaching 412 on King William Street, a street of the same width as Fifth Avenue, where the vehicles average 1.06 tons in weight and 16 484 in number. On the other hand, on no street in London was the average weight of the vehicles as great as that on First Avenue. It must be remembered, however, that in London there is an enormous number of omnibuses which are not found

on New York streets, for instance, of the 10 776 vehicles passing along Piccadilly, 32% are of this description, and average 2 tons in weight, while only 56% are cabs, averaging ½ ton each. Notwithstanding this, the traffic on Fifth Avenue approaches in tonnage per foot run that on Piccadilly in 1873. Unfortunately, there are no data available for the latter street at the present time. The traffic, no doubt, has increased largely.

It has been the custom on the Continent, and, in some cases, in England, to classify the traffic according to the number of horses attached to the vehicles, or, as it is denoted in Paris, by the number of collars. For the purpose of comparing the traffic on New York streets with that on the streets of Paris, as recorded in a series of observations made in 1881 and 1882, the New York data have been calculated on the basis of the number of collars passing the different points, and this is shown in Table 5.

For comparison with these figures, Table 7 shows the traffic on prominent streets in Paris.

The preceding data show that the traffic in Paris in 1881 and 1882 was very much greater than that on the streets carrying the heaviest traffic in New York City at the present time. In fact, no traffic has been counted on any street in any city in the world which can equal that for the Rue de Rivoli in Paris in 1881, which at that time was nearly three times as great as that on Fifth Avenue to-day, the width of the two streets being practically the same. As in the case of some of the London streets, the great tonnage carried by this street is to be attributed to the large number of extraordinarily heavy omnibuses which traverse it, these vehicles being much heavier than those used in New York or London, and each counting for three collars. If to each collar a weight of 0.5 is assigned, the tonnage on this street would amount to 534 per ft. of width, which is nearly double that on Fifth Avenue.

As has been said, according to the method adopted on the Continent, in England, and by Captain Greene in 1885, no consideration was given to the weight of the horses in calculating traffic to which the pavements were subjected from the number of vehicles enumerated. Mr. W. G. Root, District Manager of the Barber Asphalt Paving Company, of New York City, in working out the data which were presented in the engineering journals in 1905, included the

weight of the animals as well as that of the vehicles, in arriving at a conclusion as to the traffic carried by the various streets. On this basis he obtained the results given in Table 8.

To the writer, the latter method of statement, if the estimate of the weight of the vehicle and animal is correct, seems much more desirable. From the point of view of one who has been employed for many years in the construction of pavements and in observations as to the causes of their deterioration, it has become evident that the latter is due much more to the impact of the horses' hoofs, especially in the case of asphalt pavements, than to vehicles rolling quietly over the surface; this, of course, with the understanding that the base supporting the pavement is sufficiently rigid to do so satisfactorily and prevent vibration in the wearing surface.

For these reasons it seems desirable to consider the data in Table 8 as representing the true traffic on the various streets in regard to which the data were calculated, and to suggest that, in any observations made in the future, due consideration should be given to the weight of the animal as well as to that of the vehicle.

TABLE 1.—TRAFFIC ON NEW YORK STREETS, 1904, 7 A. M. TO 6 P. M. AVERAGE NUMBER OF VEHICLES.

| Street. | | Cabs. | Auto-Vehicles. | | | One-horse delivery wagons. | One-ton trucks. | Carriages. | Omnibuses. | Two-horse delivery wagons | Trucks. | | | | | | | Total Number of vehicles. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Elec. tric. | Gaso- line. | Electric trucks. | | | | | | 2- ton. | 3- ton. | 4- ton. | 5- ton. | 6- ton. | 7- ton. | 8- ton. | |
| 5th Ave., | 33d to 34th Sts. | 6 162 | 838 | 272 | 74 | 1 399 | 351 | 1 895 | 370 | 132 | 323 | 129 | 68 | 35 | 8 | 5 | 7 | 12 068 |
| 1st Ave., | 26th to 27th Sts. | 185 | 14 | 7 | 25 | 1 141 | 1 381 | 10 | 1 | 122 | 1 332 | 582 | 351 | 277 | 180 | 91 | 241 | 6 037 |
| 8th Ave., | 34th to 37th Sts. | 417 | 37 | 37 | 44 | 2 349 | 928 | 114 | 5 | 292 | 720 | 375 | 209 | 141 | 40 | 12 | 49 | 5 769 |
| Broadway, | 18th to 19th Sts. | 1 005 | 134 | 58 | 40 | 1 132 | 402 | 252 | 3 | 54 | 332 | 178 | 93 | 52 | 20 | 6 | 10 | 3 771 |
| 4th St., | Wooster St. to West Broadway. | 229 | 98 | 21 | 13 | 829 | 884 | 71 | 2 | 56 | 589 | 283 | 122 | 114 | 62 | 8 | 76 | 3 397 |
| Broadway, | Franklin to Leonard Sts. | 392 | 55 | 44 | 32 | 1 743 | 243 | 80 | 2 | 362 | 207 | 90 | 16 | 5 | 1 | 3 | 2 | 3 277 |
| 10th Ave., | 22d to 23d Sts. | 62 | 3 | 2 | 4 | 1 007 | 458 | 11 | 0 | 341 | 548 | 205 | 118 | 81 | 17 | 16 | 19 | 2 892 |
| 3d St., | Mercer to Greene Sts. | 24 | 2 | 2 | 3 | 513 | 444 | 6 | 0 | 46 | 250 | 132 | 53 | 51 | 20 | 4 | 24 | 1 574 |
| 2d Ave., | 34th to 35th Sts. | 32 | 3 | 2 | 6 | 559 | 206 | 15 | 2 | 77 | 169 | 69 | 30 | 40 | 6 | 1 | 8 | 1 225 |
| 34th St., | Broadway to 7th Ave. | 97 | 7 | 15 | 45 | 395 | 148 | 52 | 0 | 49 | 116 | 45 | 15 | 19 | 2 | 0 | 13 | 1 018 |

TABLE 2.—TRAFFIC ON NEW YORK STREETS, 1904, 7 A. M. TO 6 P. M.

| Street. | | Width, in feet. | Vehicles. | | | | | | | | Tonnage. | | | Collars. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Less than 1 ton. | | From 1 to 3 tons. | | From 4 to 6 tons. | | From 7 to 8 tons. | | Total. | Total. | Per vehicle. | Per foot of width. | Total. | Per foot of width. |
| | | | No. | % | No. | % | No. | % | No. | % | | | | | | |
| 5th Ave., | 33d to 34th Sts. | 40 | 9 588 | 79.45 | 2 357 | 19.54 | 111 | 0.92 | 12 | 0.09 | 12 068 | 9 875.0 | 0.82 | 246.9 | 16 007 | 400.2 |
| 1st Ave., | 26th to 27th Sts. | 44 | 1 555 | 25.76 | 3 342 | 55.86 | 808 | 13.38 | 332 | 5.50 | 6 037 | 13 167.8 | 2.18 | 299.2 | 10 150 | 230.7 |
| 8th Ave., | 34th to 37th Sts. | 44 | 3 172 | 54.98 | 2 146 | 37.20 | 390 | 6.76 | 61 | 1.06 | 5 769 | 7 683.8 | 1.33 | 174.6 | 8 049 | 182.9 |
| Broadway, | 18th to 19th Sts. | 25 | 2 443 | 64.78 | 1 147 | 30.42 | 165 | 4.38 | 16 | 0.42 | 3 771 | 4 244.3 | 1.47 | 169.8 | 5 033 | 201.3 |
| 4th St., | Wooster St. to West Broadway. | 32 | 1 185 | 34.88 | 1 830 | 53.88 | 298 | 8.77 | 84 | 2.47 | 3 397 | 5 772.0 | 1.70 | 180.4 | 5 091 | 159.1 |
| Broadway, | Franklin to Leonard Sts. | 28 | 2 577 | 78.64 | 673 | 29.53 | 22 | 0.67 | 5 | 0.16 | 3 277 | 2 714.4 | 0.83 | 96.9 | 4 143 | 147.9 |
| 10th Ave., | 22d to 23d Sts. | 34 | 1 421 | 49.14 | 1 220 | 42.18 | 216 | 7.47 | 35 | 1.21 | 2 892 | 4 237.8 | 1.47 | 124.6 | 4 388 | 129.0 |
| 3d St., | Mercer to Greene Sts. | 28 | 589 | 37.42 | 833 | 52.93 | 124 | 7.88 | 28 | 1.77 | 1 574 | 2 469.0 | 1.57 | 88.0 | 2 263 | 80.8 |
| 2d Ave., | 34th to 35th Sts. | 46 | 683 | 55.76 | 457 | 37.31 | 76 | 6.20 | 9 | 0.74 | 1 225 | 1 568.5 | 1.28 | 34.1 | 1 706 | 37.1 |
| 34th St., | Broadway to 7th Ave. | 24 | 593 | 58.25 | 376 | 36.93 | 36 | 3.54 | 13 | 1.28 | 1 018 | 1 251.1 | 1.23 | 52.1 | 1 415 | 58.9 |

NOTE.—The width does not include the car tracks, as these carry only a small proportion of the traffic.

TABLE 3.—TRAFFIC ON NEW YORK STREETS, 1904, 7 A. M. TO 6 P. M.

| Street. | | Width, in feet. | Vehicles. | | | | | | | | | Tonnage. | | | Collars. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Less than 1 ton. | | From 1 to 3 tons. | | From 4 to 6 tons. | | From 7 to 8 tons. | | Total. | Total. | Per vehicle. | Per foot of width. | Total. | Per foot of width. |
| | | | No. | % | No. | % | No. | % | No. | % | | | | | | |
| 5th Ave., | 33d to 34th Sts | 40 | 9 588 | 79.45 | 2 357 | 19.54 | 111 | 0.92 | 12 | 0.09 | 12 068 | 10 036.0 | 0.83 | 250.9 | 16 007 | 400.2 |
| 1st Ave., | 26th to 27th Sts | 44 | 1 555 | 25.76 | 3 342 | 55.86 | 808 | 13.38 | 332 | 5.50 | 6 037 | 13 017.5 | 2.16 | 295.9 | 10 150 | 230.7 |
| 8th Ave., | 34th to 37th Sts | 44 | 3 172 | 54.98 | 2 146 | 37.20 | 390 | 6.76 | 61 | 1.06 | 5 769 | 7 865.0 | 1.36 | 178.8 | 8 049 | 182.9 |
| Broadway, | 18th to 19th Sts | 25 | 2 443 | 64.78 | 1 147 | 30.42 | 165 | 4.38 | 16 | 0.42 | 3 771 | 4 287.5 | 1.14 | 171.5 | 5 033 | 201.3 |
| 4th St., | Wooster St. to West Broadway | 32 | 1 185 | 34.88 | 1 830 | 53.88 | 298 | 8.77 | 84 | 2.47 | 3 397 | 6 032.5 | 1.78 | 188.5 | 5 091 | 159.1 |
| Broadway, | Franklin to Leonard Sts | 28 | 2 577 | 78.64 | 673 | 20.53 | 22 | 0.67 | 5 | 0.16 | 3 277 | 2 752.5 | 0.84 | 98.3 | 4 143 | 147.9 |
| 10th Ave., | 22d to 23d Sts | 34 | 1 421 | 49.14 | 1 220 | 42.18 | 216 | 7.47 | 35 | 1.21 | 2 892 | 4 259.5 | 1.47 | 125.3 | 4 388 | 129.0 |
| 3d St, | Mercer to Greene Sts | 28 | 589 | 37.42 | 833 | 52.93 | 124 | 7.88 | 28 | 1.77 | 1 574 | 2 652.5 | 1.69 | 94.7 | 2 263 | 80.8 |
| 2d Ave., | 34th to 35th Sts | 46 | 683 | 55.76 | 457 | 37.31 | 76 | 6.20 | 9 | 0.74 | 1 225 | 1 622.5 | 1.32 | 35.3 | 1 706 | 37.1 |
| 34th St., | Broadway to 7th Ave | 24 | 593 | 58.25 | 376 | 36.93 | 36 | 3.54 | 13 | 1.28 | 1 018 | 1 283.5 | 1.26 | 53.5 | 1 415 | 58.9 |

NOTE.—The width does not include the car tracks, as these carry only a small proportion of the traffic.

TABLE 4.—TRAFFIC ON NEW YORK STREETS: COMPARISON OF 1885 AND 1904.

| Year. | Street. | | Width, in feet. | Pavement. | Vehicles. | | | | | | | Tonnage. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Less than 1 ton. | | From 1 to 3 tons. | | Over 3 tons. | | Total. | Total. | Per vehicle. | Per foot of width. |
| | | | | | No. | % | No. | % | No. | % | | | | |
| 1885 | Broadway, | near Pine St | 40 | Granite | 4 379 | 54 | 2 502 | 34 | 930 | 12 | 7 811 | 10 905 | 1.39 | 273.0 |
| | 5th Ave., | opposite Worth Monument | 40 | Asphalt. | 4 957 | 91 | 373 | 7 | 130 | 2 | 5 460 | 3 744 | 0.68 | 94.0 |
| 1904 | Broadway, | 18th to 19th Sts | 40* | Asphalt. | 2 443 | 64.78 | 1 147 | 30.42 | 181 | 4.80 | 3 771 | 4 287.5 | 1.14 | 107.2 |
| | Broadway, | Franklin to Leonard Sts | 42* | Granite | 2 577 | 78.64 | 673 | 20.53 | 27 | 0.83 | 3 277 | 2 752.0 | 0.84 | 65.5 |
| | 5th Ave., | 33d to 34th Sts | 40 | Asphalt. | 9 588 | 79.45 | 2 357 | 19.54 | 123 | 1.04 | 12 068 | 10 036.0 | 0.83 | 250.9 |

* In 1904 the width of the streets has been taken exclusive of that of the car tracks, as these carry but a small portion of the traffic. For the purpose of comparison with the data of 1885 the width of Broadway has been considered as including the car tracks in this table.

TABLE 5.—Traffic on New York Streets, 1904, 7 A. M. to 6 P. M., by Collars.

| Street. | | Width, in feet. | Vehicles. | | | | | | | Collars. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | One-horse. | | Two-horse. | | Three-horse and over. | | Total. | Number. | Per foot of width. |
| | | | No. | % | No. | % | No. | % | | | |
| 5th Ave., | 33d to 34th Sts | 40 | 8 184 | 67.8 | 3 829 | 31.7 | 55 | 0.5 | 12 068 | 16 007 | 400.2 |
| 1st Ave., | 26th to 27th Sts | 44 | 2 714 | 44.9 | 2 534 | 42.0 | 789 | 13.1 | 6 037 | 10 150 | 230.7 |
| 8th Ave., | 34th to 37th Sts | 44 | 3 731 | 64.7 | 1 796 | 31.1 | 242 | 4.2 | 5 769 | 8 049 | 182.9 |
| Broadway, | 18th to 19th Sts | 25 | 2 597 | 68.9 | 1 086 | 28.8 | 88 | 2.3 | 3 771 | 5 033 | 201.3 |
| 4th St., | Wooster St. to West Broadway. | 32 | 1 963 | 57.8 | 1 174 | 34.6 | 260 | 7.6 | 3 397 | 5 091 | 159.1 |
| Broadway, | Franklin to Leonard Sts | 28 | 2 422 | 73.9 | 844 | 25.8 | 11 | 0.3 | 3 277 | 4 143 | 147.9 |
| 10th Ave., | 22d to 23d Sts | 34 | 1 529 | 52.9 | 1 230 | 42.5 | 133 | 4.6 | 2 892 | 4 388 | 129.0 |
| 3d St., | Mercer to Greene Sts | 28 | 983 | 62.4 | 492 | 31.3 | 99 | 6.3 | 1 574 | 2 263 | 80.8 |
| 2d Ave., | 34th to 35th Sts | 46 | 799 | 65.2 | 371 | 30.3 | 55 | 4.5 | 1 225 | 1 706 | 37.1 |
| 34th St., | Broadway to 7th Ave | 24 | 655 | 64.4 | 329 | 32.3 | 34 | 3.3 | 1 018 | 1 415 | 58.9 |

1 Collar = Cabs, Gasoline Autos, 1-Horse Delivery Wagons and 1-Ton Trucks.
2 Collars = Carriages, Omnibuses, 2-Horse Delivery Wagons, Electric Trucks, Electric Autos, and 2, 3 and 4-Ton Trucks.
3 Collars = 5, 6, 7 and 8-Ton Trucks.

TABLE 6.—Traffic Records on Certain Streets in London and Liverpool, 1873 to 1884.

| City. | Street. | Pavement. | Width, in feet. | Total number of vehicles. | Tonnage. | | |
|---|---|---|---|---|---|---|---|
| | | | | | Total. | Per vehicle. | Per foot of width. |
| London.... | Gracechurch St.... | Asphalt.... | 32 | 12 148 | 13 507 | 1.11 | 422 |
| " .... | King William St... | Wood..... | 40 | 15 513 | 16 484 | 1.06 | 412 |
| " .... | The Poultry..... | Asphalt.... | 22 | 8 167 | 8 330 | 1.02 | 378 |
| " .... | Strand and Fleet St. | Wood..... | 37 | 16 208 | 13 596 | 0.84 | 367 |
| " .... | Parliament St..... | Macadam.. | 45 | 14 306 | 14 380 | 1.01 | 322 |
| " .... | Oxford St..... | Wood ..... | 57 | 16 886 | 17 076 | 1.01 | 300 |
| " .... | Cheapside..... | Asphalt.... | 32 | 9 419 | 9 260 | 0.98 | 290 |
| " .... | Leadenhall St..... | " .... | 30 | 6 128 | 7 588 | 1.08 | 253 |
| " .... | Piccadilly..... | Macadam.. | 37 | 10 776 | 9 358 | 0.87 | 253 |
| " .... | Euston Road..... | Granite .... | 44 | 12 132 | 10 658 | 0.88 | 242 |
| " .... | Brompton Road... | Wood..... | ..... | ..... | ..... | ..... | 216 |
| " .... | King William St... | Granite.... | 32 | 6 371 | 6 506 | 1.02 | 203 |
| " .... | Edgeware Road... | " .... | 43 | 8 212 | 8 376 | 1.02 | 195 |
| " .... | Regent St..... | Macadam.. | 52 | 10 796 | 9 668 | 0.90 | 186 |
| " .... | King's Road..... | Wood..... | ..... | ..... | ..... | ..... | 156 |
| " .... | Victoria St..... | Macadam.. | 40 | 6 040 | 5 780 | 0.96 | 145 |
| " .... | Sloane St..... | Wood..... | ..... | ..... | ..... | ..... | 93 |
| Liverpool.. | ..... | Granite.... | ..... | ..... | ..... | ..... | 382 |
| " .. | ..... | " .... | ..... | ..... | ..... | ..... | 232 |
| " .. | Great Howard St.. | Wood..... | ..... | ..... | ..... | ..... | 231 |
| " .. | Bold St..... | " ..... | ..... | ..... | ..... | ..... | 100 |

TABLE 7.—Traffic on Streets in Paris, France, 1881-1882, by Collars.

| Street. | Width, in feet. | Number of Collars. | Collars, per foot of width. | Total number of vehicles. |
|---|---|---|---|---|
| Avenue de l'Opera..... | 52.48 | 36 185 | 689.5 | 29 460 |
| Rue de Rivoli..... | 39.36 | 42 035 | 1 067.9 | 33 232 |
| Rue Saint-Honore..... | 28.208 | 19 672 | 697.4 | 16 589 |
| Boulevard Haussmann..... | 45.92 | 14 096 | 306.9 | 12 638 |
| Avenue des Champs Elysées | 89.872 | 14 082 | 156.7 | 12 023 |

TABLE 8.—Traffic on New York Streets, 1904, 7 A. M. to 6 P. M., Weight of Animals included with Vehicles.

| Street. | Average tonnage per vehicle. | Average tonnage per linear foot of width for 11 hours. |
|---|---|---|
| 5th Ave., 33d to 34th Sts..... | 1.64 | 481.85 |
| 1st Ave., 26th to 27th Sts..... | 3.18 | 435.58 |
| 8th Ave., 35th to 36th Sts..... | 2.28 | 296.02 |
| Broadway, 18th to 19th Sts..... | 1.97 | 299.63 |
| 4th St., Wooster St. to West Broadway..... | 2.73 | 289.18 |
| Broadway, Franklin to Leonard Sts..... | 1.74 | 202.42 |
| 10th Ave., 22d to 23d Sts..... | 2.69 | 227.45 |
| 3d St., Mercer to Greene Sts..... | 2.51 | 140.50 |
| 2d Ave., 34th to 35th Sts..... | 2.24 | 117.86 |
| 34th St., Broadway to 7th Ave..... | 2.03 | 89.22 |

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## THE CONTROL OF HYDRAULIC MINING IN CALIFORNIA BY THE FEDERAL GOVERNMENT.

### Discussion.*

BY MESSRS. H. H. WADSWORTH, FRANKLIN RIFFLE, J. D. GALLOWAY, H. DE C. RICHARDS AND STEPHEN E. KIEFFER.†

Mr. Wadsworth.

H. H. WADSWORTH, M. AM. SOC. C. E. (by letter).—Since the publication of Captain Harts' paper some additional data have been obtained relative to the hydraulics of the Yuba and Bear Rivers, and the movement of debris by them.

The construction of Barrier No. 1 has rendered possible a fairly close estimate of the quantity of water flowing in the Yuba River at various stages. A comparison of the cross-section of this dam with those of several forms of weirs, the coefficients of which in the usual weir formulas have been determined by several experimenters, gives an approximate value for its coefficient. During the high water of January, 1906, the depth of water on the crest of the dam was 5.3 ft. at the north end and 6.0 ft. at the south end. These depths indicate a flow of about 70 000 cu. ft. per sec., a determination which has been roughly checked by the United States Geological Survey at a measured cross-section near Smartsville.

During the flood of February, 1904, said to be the greatest for many years, the gauge height at The Narrows, about 6 miles above the barrier, is reported to have been 4 ft. higher than during the

* This discussion (of the paper by William W. Harts, M. Am. Soc. C. E., printed in *Proceedings* for February, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Presented at the meeting of the San Francisco Association of Members, Am. Soc. C. E., on April 14th, 1906.

flood of January, 1906. This extra depth means a discharge well up toward the 90 000 cu. ft. per sec., stated by the author to be the probable maximum. Mr. Wadsworth.

On the Bear River no recent flood discharge measurements have been made, but an extension of velocity and discharge curves, plotted from observations taken by the U. S. Geological Survey for several gauge heights, up to the maximum gauge heights observed, in connection with measured cross-sections, show that the assumed maximum flow for the Bear was nearly or quite reached during the flood of January, 1906.

The recent survey of the Bear River shows that conditions there have reached a state of comparative equilibrium.

DIAGRAM SHOWING THE VARIATION OF FLOW IN THE YUBA RIVER DURING THE FLOOD OF JANUARY 1906.

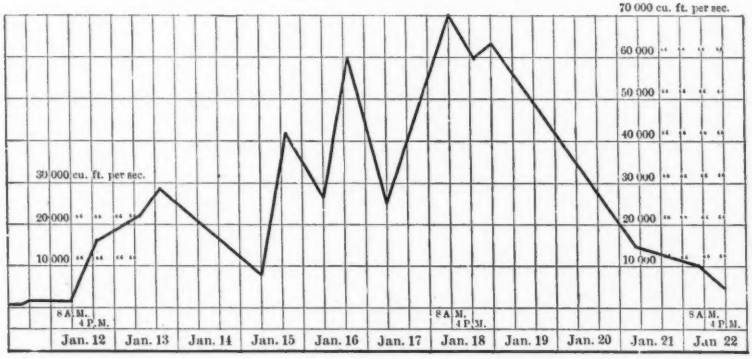



FIG. 4.

The form of the banks at the confluence of the Bear and Feather Rivers indicates that very little material is deposited in the latter by the former, and up stream, near Wheatland, the fact that alfalfa and hop fields are being cultivated between the levee lines shows that no great progressive damage is now being done from year to year.

On the Yuba, however, in spite of the fact that hydraulic mining on a large scale was stopped more than twenty years ago, there is still an extensive movement of the mining debris, as pointed out by the author, and this is likely to continue for many years. The great bulk of the material is moved during the few days of extreme high water each season. During the flood of January, 1906, the pool formed by the second step of the barrier was filled to the crest of the dam, at the center of its length, and the new deposit, extending up stream about 1½ miles, measured more than 920 000

Mr. Wadsworth.

cu. yd. The continuance of a fairly high stage of the river since the flood mentioned has filled out the corners and increased the deposit to more than 1 000 000 cu. yd.

The filling in behind the first and second steps of the dam in such a short time is roughly confirmatory of the results of the survey, which showed a fill of 15 000 000 cu. yd. of material in the stretch of river bottom between Marysville and Barrier No. 1 in the five years between 1899 and 1904.

The diagram, Fig. 4, shows approximately the variation in the flow of the Yuba during a portion of January. This shows graphically the flashy character of the floods. The total discharge between 8 A. M. on January 12th and 4 P. M. on January 22d was approximately 1 000 000 000 cu. yd. of water. During this period was deposited the great bulk of the fill above the dam, which, from the foregoing figures, amounted to less than one-tenth of 1% of the mass of water by which it was transported. In addition to the material pushed along the bottom by the flood wave, a large quantity, of course, was carried over the dam in suspension. This may easily have amounted to one-third of the quantity deposited above the dam.

During the present season a spillway of sufficient capacity to carry the entire flow of the river for six months of the year will be built. As succeeding steps are added to the dam the spillway will be increased until, when the final height of the dam has been reached, its capacity will be such that water will flow over the crest of the dam only during extremely high water.

Besides the relief which this spillway will afford to the dam, its value as an accessory in the construction of succeeding steps will be very great, as the difficulties of turning the water and making the closures will be avoided.

Mr. Riffle.

FRANKLIN RIFFLE, M. AM. SOC. C. E. (by letter).—The author has properly prefaced his excellent description of the methods used to control hydraulic mining in California by a brief historical review of this important industry. This feature adds materially to the value and interest of the paper. The development of hydraulic mining gave rise to many unique engineering problems which were boldly attacked and admirably solved by California engineers, whose achievements are but slightly known to civil engineers outside of that State. It is much to be regretted that an industry which has contributed so largely to the material wealth, not only of California, but of the entire country—which has placed in the hands of engineers hydraulic data of incalculable value—and is so distinctively an American enterprise—is not mentioned in the index of papers published in the *Transactions* of this Society. It is greatly to be hoped that some California member, familiar with the history of hydraulic mining, will rise to the occasion, and contribute a suit-

able paper on this subject before many important details of the early stages of the industry are lost to the engineering profession. Mr. Riffle.

The evolution from small volumes of water, low pressures, canvas pipe, and crude, improvised nozzles, to large volumes of water, high pressures, heavy double-riveted pipe of large diameter, and the hydraulic monitor or giant, took place in a surprisingly brief period, and, when taken in connection with the construction of ditches, flumes, tunnels, dams and reservoirs, often under unprecedented conditions, marks an important epoch in engineering history which deserves to be fittingly commemorated in the annals of America's leading society of civil engineers. It is well to remember that many of the great things accomplished by the engineers of to-day are to a very great extent the direct result of the experiments, mistakes, failures and successes of the engineers of yesterday. And so in California the engineers who were engaged in developing the industry of hydraulic mining more than a quarter of a century ago, through their failures and successes, have prepared the way for many of the spectacular achievements of the hydraulic and electrical engineers of the present day.

The author's statement that "the industry of hydraulic mining was finally completely vanquished," although evidently intended to apply to the region drained by the Sacramento and San Joaquin Rivers, may be misleading to those who are not residents of California. Hydraulic mining in California has never been prohibited by statute, although the decree of the United States Circuit Court which perpetually enjoined and restrained the North Bloomfield Mining Company from discharging mining debris into the Yuba River or any of its tributaries, had the effect of closing all hydraulic mines, the operation of which clearly caused injury to navigation or private property. In the northern part of the State, however, in the region drained by the Klamath River, hydraulic mining has been prosecuted without any interference whatever. Section 1424 of the Civil Code of California provides that:

"The business of hydraulic mining may be carried on within the State of California wherever and whenever the same may be carried on without material injury to the navigable streams or the lands adjacent thereto."

These conditions exist in the territory drained by the Klamath River. This, the second river in size in the State, is a typical mountain stream. It has a rapid, torrential current, and flows through a succession of deep gorges which extend almost to its mouth. There are practically no agricultural lands along its banks, and it is hopelessly unnavigable. High benches of auriferous gravel aggregating thousands of acres lie along its banks and those of its tributaries. Hydraulic mining operations have been conducted in this locality

Mr. Riffle. for many years with satisfactory results, the gravel yielding from $5 000 to $25 000 per acre. Although most of the mines are small, their aggregate yearly production of gold is very considerable. A few mines, however, operate on a large scale. The La Grange Mine, in Trinity County, for instance, has one of the largest hydraulic plants in the world. With high banks (the maximum height being 300 ft.) and 9 000 miner's in. of water available, it has been possible to hydraulic from 10 000 to 12 000 cu. yd. of gravel per day. To convey this large volume of water from the source of supply to the mine it was necessary to construct 16 miles of flumes, ditches, pipes and tunnels. This conduit contains a tunnel 1½ miles long, and a 30-in. riveted siphon nearly 1 mile in length operating under a pressure of 450 lb. per sq. in. at its lowest point.

Without going further into detail, it may be concluded that hydraulic mining promises to be an important industry in California for many years—especially in those localities which are more fortunately situated than the region described by the author.

Mr. Galloway. J. D. GALLOWAY, M. AM. SOC. C. E. (by letter).—The engineers in charge of the construction of the Yuba barrier are to be congratulated on the success of their effort to build even a low dam across the Yuba River. Since the paper was written the river has been in flood, and, as no damage to the barrier has been reported, it may be considered that the second step in the dam will stand.

The writer is familiar with the Yuba River, and offers the following comment upon the subject of the paper. It does not seem, from the author's statements that any reliable estimate could be made of the quantity of debris now in the channels of the various forks of the river. Hence the ability of works, as designed, to control the situation, is open to question. According to the author, about 1 000 000 cu. yd. of earth per year are being mined, and this is restrained by log and brush dams. It is the writer's opinion that, in time, this will result in renewing the problem of the lower river. The brush and log dams will certainly decay, and, if upon any considerable stream, the debris will then be carried to the lower reaches and deposited. Owing to the fact that most of the tributaries are nearly or quite dry for a period every year, the decay of the dams will be rapid.

The head dam of the Bay Counties Power Company, 8 miles above Colgate, was formerly a wood-crib dam about 40 ft. high. It failed two years ago, after a service of some thirteen years, and was replaced by a stone dam. The writer examined the timber of this dam and found that, although it was in fair condition, it showed evidences of decay. Before failure the river was filled to the dam crest with debris, and of course, this went out with the dam. The plan of this dam was very much like the plan shown by the author,

and its failure is cited as an evidence that the dams built under the permits of the Debris Commission will fail in time, and in most cases the impounded material will be washed down the river. It is not quite as bad, however, as turning the debris directly into the stream, but, if the practice is continued, the condition of affairs will in time be nearly as bad as ever. Mr. Galloway.

Referring to the impounding of debris by the barrier, the author does not state the cubic contents of the basin above the dam, nor of the settling basins below. The quantity of debris brought down by the river is given as about 3 000 000 cu. yd. per year, but, without knowing the storage capacity of the basins, the ability of the works constructed to control the situation is not evident. A statement is made that after the first step was completed in 1904, the first freshet filled the basin to the crest of the dam.

The second step of the dam of course added a greater cube to the basin, and the author probably now knows what effect the late floods have had upon it.

Referring to the dam, the writer believes that the addition of two more steps, making it 36 ft. high, will be a serious menace to the entire structure. While part of the flood will be carried by the spillway, a relatively small quantity of water may do considerable damage to the toe. Water passing the series of rollways does not lose much of its energy, most of it being expanded in the pool at the toe.

The training walls from Daguerre Point to Marysville seem to the writer to be the best part of the scheme. Their value lies, not so much in lands reclaimed, as in preventing the river from washing the entire deposit of debris into the Sacramento River below.

The foregoing is not to be considered as a criticism on the design of the dam. It has been built on the shifting sands of a violent river, and the engineers are to be congratulated upon the success of the work. It is believed, however, that the building of temporary dams in the mountains to restrain debris is bad policy. Gold is not wealth, and the State would be better off if hydraulic mining had never been invented.

It is possible that the author has at hand the capacities of the basin above the barrier, intended to restrain the material of larger size, and of the settling basin for the finer material, in which case, an estimate of their ability to impound the debris could be made. Without this, it would seem that the project is open to question, as suggested above.

H. De C. Richards, M. Am. Inst. M. E. (by letter).—Mr. Hart's very able, comprehensive and highly educational paper refers to the protection for navigable streams developed on account of the great damage done by dumping mining debris into the Mr. Richards.

Mr. Richards.

tributaries of those streams, but no reference is made to the debris from slides, which is steadily increasing and, in some sections, is much more serious than the mine dumpage.

The "Caminetti Law" so-called, has resulted less expensively in the long run for the miners than the fighting of many debris suits—some honest and many blackmailing.

The writer will describe briefly the conditions on the non-navigable streams of Northwestern California.

Several years' experience in hydraulicing gravels in Humboldt and Siskiyou Counties impels the writer to state that there are four counties in California where hydraulic mining can be done without injury to navigation or agricultural interests. The counties of Del Norte, Siskiyou, Trinity and Humboldt (north of Eureka) have an area of some 8 000 000 acres, or about 12 000 sq. miles.

The Klamath and Trinity Rivers, and the tributaries thereto having workable auriferous gravels within reasonable dumping distance, cover a length of about 600 miles. The lower 60 miles of the Klamath River has a fall of about 490 ft.

Placer mining began in that section about fifty years ago, and seems to have increased steadily in number of openings until some ten years ago, when many of the larger workings had reached the hill rock. The small "one-man workings" are innumerable; a few large mines are still operating on the Klamath, Trinity, Salmon and Scott Rivers, all of which, with the many smaller streams, flow to the Pacific through the Klamath. The lower 45 miles of this river has no large mines; the gravels are on the upper benches, some as high as 2 000 ft. above the river, with no water available for mining.

The mine now being operated by the writer at Orleans has averaged a clearing of about 1 acre of bed-rock per month with a full flume (5 by 3 ft., with a gradient of 10 ft. per mile) under a head of about 250 ft., and with banks from 50 to 80 ft. high. New workings, just opened, give 173 lb. static pressure on the gauge, that is, 402 ft. head. The same gauge indicates 120 lb. on the rear casting of a No. 4 giant, with a 6.5-in. nozzle, and with an overflowing penstock. There are several larger workings on that river, and the season is of about the same length, from 8 to 10 months—usually 8 months.

The whole country "slides easily." During the wet season, really phenomenal slides occur, stripping precipitous patches of bed-rock sometimes an acre or more in area and having depths of more than 100 ft. In one instance a length of about 1 500 ft., and more than 100 ft. thick, slipped into the Klamath River, completely damming it for some hours. Of course, much damage

was done a few hours later when it broke through. In the writer's opinion, the mining has not in the past and does not now put as much debris in the rivers as the slides in wet years. Mr. Richards.

Carefully kept rain gauges have recorded as follows:

| | |
|---|---|
| 1900-01 | 51.54 in. |
| 1901-02 | 51.68 " |
| 1902-03 | 59.30 " |
| 1903-04 | 82.10 " |
| 1904-05 | 44.27 " |

In spite of these conditions, the rivers have not filled up, and, in fact, the Klamath and Trinity Rivers are so swift that they almost reach the normal scoured condition at any heavy flood season. Bars form and disintegrate from season to season, according to the stage of the water. The formation of a bar at any point of course indicates an increased jettying beyond.

Indian dugouts are the only craft the rivers float, and, aside from casual blackmail suits assisted by legal gentlemen on contingent fees, there is little to fear from legal restrictions in that section. The Honorable John F. Davis says that in these river basins the only foe with which the industry has to contend is the occasional blackmailer. The writer might add that the ranching which might be affected by the mining is ridiculously small, and that all the ranching land is nearly always more valuable for mining.

Many excellent quartz leads have been opened in that section, and a large number are mines in operation. Prospecting is more than encouraging in some of the newer districts, but is helped by the placer mining, and there are no complaints.

The following is from the Government Report on gold and silver production in 1904:

"Hydraulic mining property is in small demand in that area (drainage basin, San Joaquin and Sacramento Rivers), and few new mines are opened. Numbers have had their licenses withdrawn for violation of the rules of the commission granting them. Some changes in the laws will have to be made if hydraulic mining is ever again to flourish in this section.

"It is proper to note, and should be borne in mind by those interested, that these conditions exist only in the drainage area referred to. In all other parts of the State there are no restrictions on hydraulic mining. The extensive hydraulic operations in Siskiyou and Trinity Counties, and the smaller ones, in Humboldt and Del Norte Counties have always continued without interference by the people or the laws; and it is for this reason that Trinity and Siskiyou Counties now lead all others in this branch of mining. The drainage of all the streams in that area is ul-

Mr. Richards. timately into the Klamath River, which is a non-navigable stream, and empties directly into the Pacific Ocean, where all the debris finally disappears without possibility of damage to any one.

"Each mine may therefore dump its debris at convenience and the spring freshets carry it out, leaving a place for another dump the following year. Naturally, under these conditions (which formerly prevailed in the area of the State now under restriction), no impounding basins for tailings are necessary, nor is there any Federal supervision whatever. The quantity of gravel to be washed is therefore limited only by the quantity of water which can be brought to bear under pressure against the banks of gravel."

Mr. Kieffer. STEPHEN E. KIEFFER, ASSOC. M. AM. SOC. C. E. (by letter).—The author, in his analysis of the physical and industrial conditions leading to the cessation of hydraulic mining in the tributary water-shed of the Sacramento River, and the creation of the California Debris Commission, has clearly given the underlying reasons for the existence of the problem, and with the proposed method of its solution, that has proved too large for the State of California to cope with unaided, and too complex with bitter politically and socially to be dealt with in direct control by other than the Federal Government.

The bitterness engendered by the fight of a quarter century ago is a thing almost unknown to later comers in the State, especially if residence or business has not placed them in direct touch with the territory affected.

To-day, however, the feeling of animosity between the people of the valley and the people of the hills remains much the same as ever; the miners ever hope to mine and the ranchers in the valley jealously watch to see that the danger does not threaten.

As evidence of this fact may be cited a meeting of the ranchers, in the fall of 1904, at Marysville, called to consider the question of proceeding against the gold dredges at work along the Feather River at Oroville, and on the Yuba at Daguerre Point—the two latter dredges being those referred to by the author as building the lower diverting barrier across the Yuba.

Floods during the previous season had covered with sand large areas along the Feather River, and this was attributed to the disturbance of the gravel deposits in the rivers by the dredges, despite the fact that, of the forty dredges operating, only three were directly in the river channels and handling recent debris deposits.

When it was pointed out that the effect of the dredges was to cover the unstable surface sands and fine gravel with 30 ft. of coarse cobbles, thereby forever restraining the fine deposits from further movement in the stream, the agitation came to a sudden end.

Mr. Kieffer.

At about the same time an attack was made upon the dredges of the American River field, the press of Sacramento claiming that the city pipes were filling with sand as a result of the dredges excavating gravel at Folsom, 22 miles distant.

These dredges were operating at a distance of ¼ mile from the channel of the American River, from 40 to 60 ft. in elevation above it, and tailed back into the river from ½ to 1 cu. ft. of water per sec. to each boat.

These cases serve to indicate how vigilant a watch is kept upon gravel mining in any form.

No other comment is needed upon the damage resulting to the valley lands from former hydraulic mining. While this vigilance guarantees immunity for the future, the writer feels that excessive alarm is unnecessary. To all intents and purposes hydraulic mining in the Sacramento water-shed is a thing of the past.

The author estimates that 1 000 000 cu. yd. of gravel are excavated per year at the present time. Taking his estimate of the yardage in the streams as follows:

| | | |
|---|---|---|
| Lower Yuba | 333 000 000 | cu. yd. |
| Bear | 66 000 000 | " " |
| Sacramento | 108 000 000 | " " |
| Other tributaries (assumed by writer) | 100 000 000 | " " |

There is a total of 607 000 000 cu. yd. of gravel remaining in the streams.

If to this is added the *pro rata* of material estimated by the State Engineer in 1880 as being carried to Suisun and San Francisco Bays in suspension, the grand total is 760 000 000 cu. yd. of gravel mined and dumped into the streams in a period of about 25 years. No doubt the true volume is greatly in excess of this.

Upon this basis, it would take 760 years, at the present rate of hydraulicing, to cause a trouble of the magnitude confronting the Commission to-day, granting that all the gravel was allowed to go into the streams.

Comparatively few gravel deposits of the Sierras suitable for hydraulicing on any large scale have favorable sites for the storage of debris.

The necessarily small scale of the operations, combined with the added cost per cubic yard for restraining works, confines operations to the better paying or more favorably located gravels; hence, as long as the present regulations are in force, the field can never be greatly enlarged.

Granting that it is an open question as to whether or not the

Mr. Kieffer. type of restraining dams specified will prove a permanent barrier to the impounded debris, the writer cannot see that the occasional failure of a dam, in the course of time, can have any sigificant effect upon the problem as a whole, provided the general restrictive regulations of the present are enforced.

As far as possible, hydraulic mining should be encouraged. This the Debris Commission has apparently endeavored to do, but the results at best can be no more than a virtual wiping out of the industry in the Sacramento water-shed, thereby surely solving this phase of the problem.

The more momentous problem of what to do with the millions of cubic yards of debris already in the streams, however, is not as easily solved by restrictive measures. The Yuba project, so fully outlined by the author, cannot fail to impress one with the magnitude of the undertaking.

Although the Yuba is the worst offender, it is adapted to the plan of holding back the debris better than any other river of which the writer knows. Probably physical conditions could not be found elsewhere that would permit works of such magnitude to be constructed for such low cost.

Conditions are certainly unusual which will permit the Government to have built free of cost such an essential part of the scheme as the diverting barrier at Daguerre Point, with a height of 30 ft., a width of 200 or 300 ft. and a length of 2½ miles. Of the south training wall, 2 miles will also be constructed in a similar manner. The dredges building these banks excavate to a depth of 60 ft.

Even when gold values in the gravel of the river-bed fall below pay, as Marysville is approached, the construction of the south training wall should be effected at a very low figure by this method.

The great width of the Lower Yuba in its natural channel above Daguerre Point affords an unusual amount of storage for such a stream. Below Daguerre Point the width of 2 to 3 miles between levees would afford much greater room for subsidence outside of the training walls than is provided in the settling basin, although much of the most available part of this area on the south side will probably be mined by the dredges.

The elevation of the river-bed above the very flat valley lands makes the settling basin a very practical and easily accomplished part of the plan.

Barrier No. 1 is an interesting piece of engineering, the ultimate success of which seems to be assured. The length of the structure, its proposed height, the shifting character of the foundation, the floods to be passed, and the low cost for a virtually perma-

nent structure under the conditions, are all circumstances that will cause its future to be watched with interest. Mr. Kieffer.

The question of maintenance, in a structure with such an exposure of concrete face to the wear of passing gravel, may prove serious. The author states that during the first winter the concrete facing to a depth of 2 in. was cut out in places.

The writer has had experience along this line upon a dam built across the American River. The dam above the rubble masonry was crested with T-rails on each edge and filled, for a depth of from 6 to 8 in., to the tops of the rails, with concrete composed of 1 part cement and 2 parts river gravel passing a 1½-in. screen. This was entirely cut out during the first season; was replaced and cut out the next year, and finally replaced with 2-in. pine plank set between the rails.

The greatest damage from such erosion occurs during the middle stages of the river, when only the finer materials are being transported. That this danger is anticipated in Barrier No. 1 is indicated by the construction of a wasteway, 400 ft. long and 4 ft. deep, sufficient to carry the ordinary river flow. This will undoubtedly mitigate the trouble, but will not entirely remove it.

There is no doubt that the ordinary aggregate of the concrete will withstand this wear better than a strong mortar.

That the plan in general outlined by the Commission for the control of the debris of the streams is probably the most feasible one, there can be little doubt. How far it can be made beneficial is a question, and is largely a matter of topography and money.

The settling basin, diverting barrier and Barrier No. 1 of the Yuba project will probably impound from 40 000 000 to 45 000 000 cu. yd. of material. At the rate the lower Yuba basin filled, from 1899 to 1904, as given by the author, these works will be filled in about 10 or 15 years.

Other rivers, notably the American, afford poorer opportunity for impounding debris than the Yuba. In this case the river is frequently in flood when the Sacramento is not.

It is essential that all coarse material capable of being deposited in the slow-moving navigable streams should be held back if possible, but how far this can be done with the relatively small works capable of construction for the purpose only time will prove.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## NEW FACTS ABOUT EYE-BARS.

### Discussion.*

BY MESSRS. MACE MOULTON, JOHN D. VAN BUREN AND J. W. SCHAUB.

Mr Moulton. MACE MOULTON, M. AM. SOC. C. E.—The author has stated that, under ordinary working stresses, the elongations in the shorter bars differ from those in the longer bars. Does it follow, therefore, that the general methods of computing the deflections will have to be modified on account of elements introduced by the difference in the lengths of the bars? This might occur, for example, in the case of a cantilever in which the top slopes toward the ends of the truss.

In the ordinary method of computing deflections, this difference in the lengths of the bars is usually taken into account, but, from the author's statement, it would seem that the deductions would be necessarily different in the case of bars of different lengths. As a result of the author's tests, is it possible to compute approximately how much allowance should be made?

Mr. Van Buren. JOHN D. VAN BUREN, M. AM. SOC. C. E. (by letter).—While reading Mr. Cooper's valuable paper, it occurred to the writer that a rubber eye-bar would act in very nearly the same manner as a steel one, within the limits of elasticity, and would show the strains plainly on a small scale. The experiment was made, and the results illustrated by Fig. 11 are submitted at the suggestion of the author, who informs the writer that the lines of the rubber eye-bar correspond exactly in character with those of the large steel bars of his own experi-

* Continued from April, 1906, *Proceedings*. See January, 1906, *Proceedings* for paper on this subject by Theodore Cooper, M. Am. Soc. C. E.

Mr. Van Buren

EXPERIMENT WITH RUBBER EYE-BAR

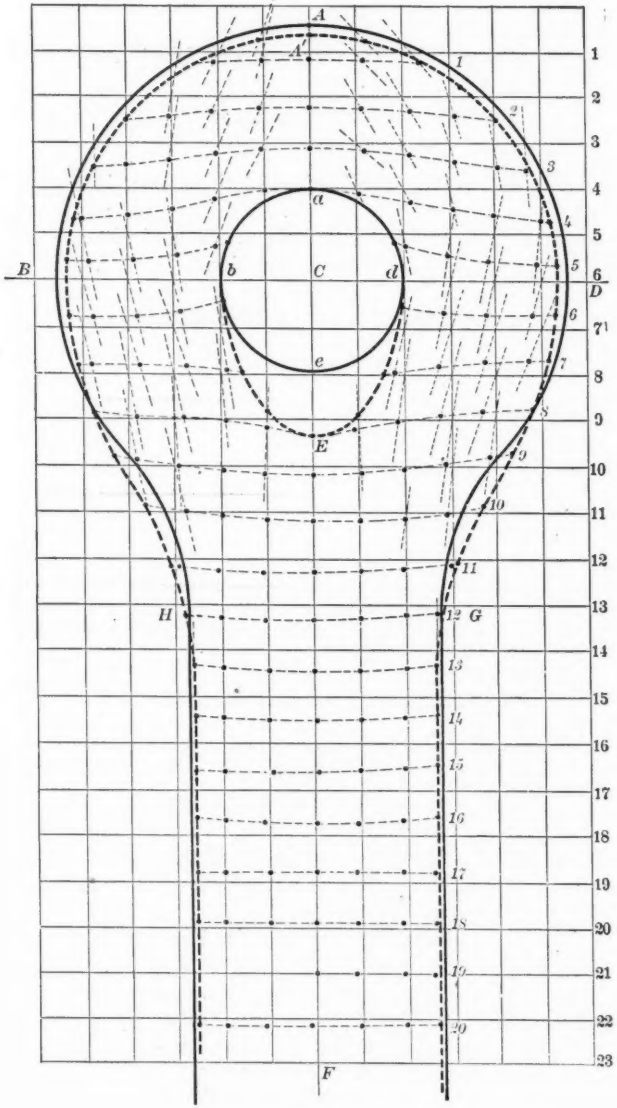



FIG. 11.

Mr. Van Buren. ment. The writer is in hopes that a more elaborate experiment with rubber may lead to results of some practical importance in determining the distribution of the stress quantitatively as well as qualitatively.

The dimensions of the eye-bar were as follows:

Neck $= 1\frac{3}{8}$ by $\frac{1}{2}$ in.;
Eye $= 2\frac{3}{4}$ in., outside diameter;
Pin $= 1$ in. diameter.

The bar, before the application of the stress, is shown in full lines, with squares inscribed on it. The bar, after the application of the stress, is shown in dotted lines. The pin-hole, as distorted by the stress, is shown by the dotted line, *a b E d*. The slanting dotted lines show the directions of the strains or flow. The small dots show the corners of the squares after distortion by the stress.

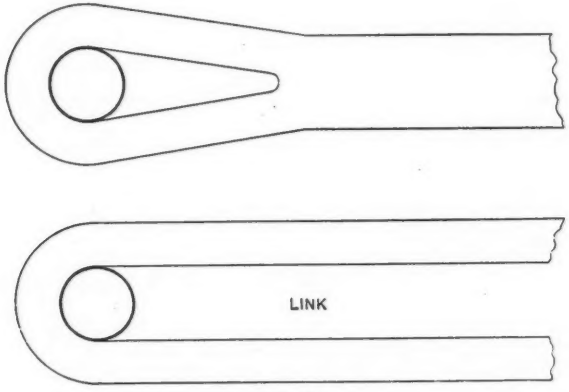



FIG. 12.

The difference between the areas of the original and the distorted squares, or between their sides or diagonals, measures approximately the stress at any particular place; tensile if the distorted squares, or lines, are the greater; compressive if they are smaller, with intermediate shearing stress.

The following indications are noted: The maximum stress is near the pin, along the lines, *b E* and *d E*, and is excessive, while the stress on the outer edges, *D* 8 and *B* 8, is comparatively small. The cause of this is evidently the bending action on each side of the pin just below *B D*, which increases the tension at the pin and reduces it on the outer edges. At *a*, for about half way to *A*, there is compression, and for the remainder of the distance there is tension; so that there is a neutral point between *a* and *A*. The top of

the eye above line 4, or line 5, appears to be strained somewhat in the manner of a beam. There is compression at *E*, where the two streams of the flow meet. There is apparently a curved boundary of shearing stress starting near *b* and cutting *a A* below *A*, and ending near *d*, surrounding the compressed area. Mr. Van Buren.

The excessive stresses and strains in the steel eye-bars, at and near each side of the pin-holes, account for the permanent elongations of the pin-holes even under moderate stresses, discovered by the author.

With a solid having considerable compressibility and a characteristic texture, however, the experiment is not complete without the measurement of the distortions in thickness, that is, in a direction perpendicular to the face of the bar, or diagram. As rubber has very little compressibility—in other words, has a very large modulus of elasticity of volume—it is evident that the volumes of the prisms represented by the squares will remain nearly constant, and that, therefore, the changes in areas of the squares will be accompanied by proportional changes, of an opposite character, in the thickness. Practically, with rubber, the coefficient of transverse linear expansion or contraction must be one-half that in a longitudinal direction—that of the load. The relations between the stresses and strains, in such a case, are comparatively simple; but, with more compressible solids having complex textures, it is difficult, if not impossible, to formulate this relation, even with a complete record of the distortions in the three directions. While it may not be possible to determine the stresses from the strains by the distortions in area alone, these distortions furnish a safe guide to the practical experimenter in search of the best shape—which requires the greatest possible uniformity in the stresses and strains. Progressive tests, marking the points of set and rupture, as carried on by the author, are the only safe guides. The mathematical theory of elasticity applied to a diagram of strains in a solid of complex structure leads to nothing practical.

Aside from considerations relating to the difficulties of manufacture, the results of this little experiment seem to point to the modifications indicated by Fig. 12 as remedies for the excessive stresses adjoining the pin. The excess in these shapes could be considerably reduced.

J. W. Schaub, M. Am. Soc. C. E. (by letter).—The results obtained by the author are not new. As he says, referring to his notes on the Eads Bridge, he finds, in pulling some iron eye-bars up to a proof stress of 18 000 lb. per sq. in., that a permanent deformation took place in the eyes. If the writer may be pardoned for the transgression, it may not be out of place to say that he believes the history of the building of the Eads Bridge to be the greatest educator in the art of bridge building, even to-day. Mr. Schaub.

Mr. Schaub. In those days it was customary to pull all eye-bars, in the shop, up to a proof stress, usually twice the working stress, or about 18 000 to 20 000 lb. per sq. in. This applied to all iron eye-bars, and was the accepted practice until the advent of the steel bar. This test was for the purpose of developing any flaws in the head which might exist in the weld; but, as far as the writer knows, it never developed anything, except that a permanent set was produced in the head of the bar. This fact was well known, and in looking over his notes on iron eye-bar tests made at Edge Moor, in the period from 1881 to 1883, the writer finds in many cases the note that a permanent set took place in the head of the bar. This deficiency was first noted when the original mill scale and cinder began to flake from the head of the bar, sometimes back of the pin, but usually near the neck of the bar. The permanent set given to the bar was never as much as $\frac{1}{32}$ in., so that little or no attention was paid to this deficiency, and, as long as the bar did not ultimately fail in the head, it filled all the requirements.

These distortions are not confined to eye-bars. They will be found in compression members, as well as in tension members, and in riveted connections as well as in pin connections; in fact, in all cases where the stress is applied to a theoretical point in the member, and where insufficient means are provided for distributing this stress into the body of the member. This defect is inherent in all designs, more or less, and cannot be avoided without providing a sufficient amount of extraneous material in the connections to distribute the stresses properly, within the limits of elasticity of the materials.

In the case of eye-bars, the difficulty can be overcome to a great extent by thickening the heads; and, at the same time, making the heads elliptical, or longer, so as to increase the metal in front and back of the pin. This was the shape of the heads made on iron bars, before the circular head came into general use, and should never have been abandoned.

The criticism offered by the author as to the present form of eye-bar is just, and the defect should be remedied.

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# PAPERS AND DISCUSSIONS.

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## THE ECONOMICAL DESIGN OF REINFORCED CONCRETE FLOOR SYSTEMS FOR FIRE-RESISTING STRUCTURES.

### Discussion.*

BY MESSRS. F. P. SHEARWOOD, MANSFIELD MERRIMAN, A. H. PERKINS, LANGDON PEARSE, C. B. WING AND JOHN S. SEWELL.

Mr. Shearwood.

F. P. SHEARWOOD, M. AM. SOC. C. E. (by letter).—Captain Sewell's advocacy of a system which eliminates as far as possible all uncertainties in this popular mode of construction will recommend itself to all.

Although the various formulas for computing the strength of beams do not differ greatly in their final results, the many discussions on the subject, by their very existence, prove that the distribution of the stresses (especially of the so-called shearing stresses) is still an unsolved problem, a clear conception of which is not yet reached.

Tests on specially prepared specimens, or on such as have been carefully watched during construction, do not by any means fully furnish the desired information, for until the stresses in a reinforced beam can be analyzed with at least the same degree of confidence in the result as is permissible in steel construction, this method must give occasion for skepticism.

The writer believes that tests, almost invariably, have been made for a single loading, and it is as yet probably unknown whether beams of this construction do not deteriorate under frequent load-

* Continued from April, 1906, *Proceedings*. See December, 1905, *Proceedings* for paper on this subject by John S. Sewell, M. Am. Soc. C. E.

Mr. Shearwood.

ings. Many authorities seem to admit that the concrete in the reinforced or tension side of a beam is strained beyond its strength when the beam is loaded to its working capacity, therefore it follows naturally that it is more or less injured, and possibly serious harm will occur with frequent loadings.

From the very small deflections recorded under test loads on these beams it appears to be evident that the steel reinforcement is not performing the work for which it was designed, and therefore the concrete is performing a duty for which it is not safely capable, and, by being stressed repeatedly to its ultimate strength, it is likely to be fractured. How the destruction of the tension value in the concrete will affect its adhesive qualities should be ascertained before reliance is placed on the permanency of reinforced concrete.

A series of experiments to discover whether reinforced concrete can fail by fatigue, or to find out at what unit stress concrete can be strained when reinforced, without deterioration, would be a valuable addition to the useful knowledge on this subject.

Mr. Merriman.

MANSFIELD MERRIMAN, M. AM. SOC. C. E. (by letter).—The author's method does not seem to be a satisfactory one for the design of beams, because his curve giving the distribution of stresses above the neutral axis was deduced from tests in which concrete was ruptured under compression. While his Equations 1 to 5 may apply very well to cases of the rupture of beams, they seem to be inapplicable to problems of design, since the stress-strain curve for rupture is very different from that which prevails when the concrete is stressed only to such values as are allowed by specifications. The unit stresses that appear in these formulas are those of the ultimate compressive strength of the concrete and the elastic limit of the steel. In designing a beam, however, the allowable compressive unit stress in the concrete should not be higher than about one-sixth of its ultimate strength, and the allowable tensile unit stress in the steel should not be higher than about one-half its elastic limit. To use the author's formulas for the design of beams, two methods may be used: first, to divide his $f_c$ and $t_s$ by factors of safety, in order that the working unit stresses may agree with those required by the specifications; or, secondly, to multiply the given maximum bending moment by a factor of safety. While both these methods are often used, it is maintained by the writer that both are illogical, and that neither of them leads to reliable results. When a beam is to be designed to carry a given bending moment under assigned unit stresses, the design should be made from formulas in which that bending moment and those unit stresses appear, and these formulas cannot be derived except from stress-strain curves which agree with those unit stresses. The object of establishing formulas for design is to determine the proportions of beams which shall

Mr. Merriman.

have the safe required unit stresses under the given bending moments. Such formulas cannot be expected to apply to cases of rupture, neither can formulas set up for cases of rupture be expected to give reliable results in designing.

The author's conclusion, that the greatest economy is secured in designing a reinforced concrete beam when the cost of the steel is equal to the cost of concrete above the steel bars, cannot be accepted by the writer. The author's investigation, starting with his Equation 10, seems to be incorrect, because it assumes the depth, $d$, to be a variable quantity, while his Equations 2 to 5 determine this depth for given values of the unit stresses. That is to say, the solution of these four equations, which are correct for the stress-strain curve adopted by the author, give the depth, $d$, of the beam, and the section area, $a$, of the steel per unit of breadth, in terms of the assumed unit stresses. Now, if these quantities are determined from the fundamental equations, it is certainly not in order to derive one or both of them later by supposing that they are variables, thus introducing an assumption which contradicts the fundamental conditions of equilibrium.

Another objection to the author's investigation is that he takes $h$, in Equation 6, as the constant number, 0.85, after having shown that its value ranges from 0.83 to 0.92. Now, a discussion of Equations 2 to 6 will show that this assumption fixes the steel section area at 1.13%; and, after the percentage of steel is thus fixed, it is difficult to see how it can later be made to vary with the relative costs of the steel and concrete.

There can be no doubt, however, that the proper design of a reinforced concrete beam involves the question of minimum cost. This, in the writer's opinion, is to be determined by selecting proper allowable values for the unit stresses in the steel and concrete. For the concrete the highest compressive unit stresses allowed by the specifications should be used, usually about 500 lb. per sq. in. for 1:2:4 concrete, and about 350 lb. per sq. in for 1:3:6 concrete. The tensile unit stress for the steel, however, cannot be arbitrarily assumed, but must be selected so as to make the cost of the beam a minimum, provided it be not greater than the highest value allowed in the specifications. If the tensile unit stress for the steel is taken high, the section area of the rods will be small and the beam will be deep; if it is taken low, the section area of the rods will be large and the beam will be shallow. The proper tensile unit stress to be used should be that which makes the total cost of steel and concrete a minimum.

When concrete is stressed in compression up to about 500 lb. per sq. in., the stress-strain curve is found to be closely a straight line, and hence a straight line should be used above the neutral axis

Mr. Merriman.

in order to deduce formulas for designing. Under a small bending moment, there is also tension in the concrete on the lower side of the beam; but, under the maximum bending moment for which the beam is to be designed, these stresses are allowed to equal the ultimate tensile strength of the concrete, so that hair cracks occur. The entire tensile resistance of the concrete below the neutral axis, however, cannot be entirely overcome, but tension exists for a short distance below that axis, and should be taken into account in deriving formulas for the design of beams. The stress-strain curve for these tensile stresses is known to differ somewhat from a straight line, but, on account of the small area under tension, it may be considered as straight for a certain distance.

For 1:2:4 concrete the allowable compressive stress is about 500 lb. per sq. in., and the ultimate tensile strength about 250 lb. per sq. in. For 1:3:6 concrete the allowable compressive stress is about 350 lb. per sq. in., and the ultimate tensile strength about 175 lb.

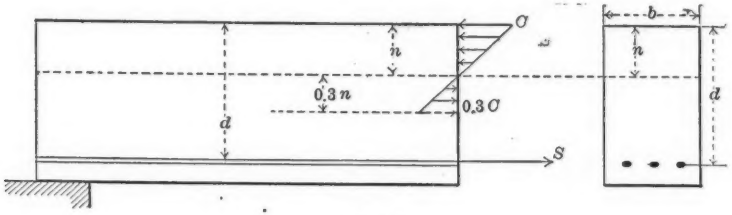



FIG. 32.

per sq. in. Hence the ultimate tensile strength of concrete is about one-half of the allowable compressive stress on the upper surface of the beam. Let $C$ be the compressive unit stress allowed by the specifications for the upper surface of the beam, and $n$ be the distance of the neutral axis below that surface; then, under a straight-line law, the greatest tensile unit stress in the concrete will be $\frac{1}{2}C$ at the distance, $\frac{1}{2}n$, below the neutral axis; but, on account of the known deviation of the stress-strain curve in tension from a straight line, it will be best to apply that law only as far as $0.3n$ below the neutral axis, thus making $0.3C$ the greatest tensile unit stress, and neglecting all tensile resistance lower than $0.3\,n$ from the axis. Fig. 32 shows, then, the internal stresses proper for consideration in deriving formulas for the design of reinforced concrete beams.

The equations of equilibrium for a rectangular beam of breadth, $b$, under a given bending moment, $M$, are now readily written. Let $A$ be the section area of the steel rods, the center of which is at the distance, $d$, below the top of the beam, and let $S$ be the tensile unit stress in these rods.

Mr. Merriman.

The first condition is that the sum of all the horizontal tensile stresses shall equal the sum of all the horizontal compressive stresses, whence,

$$A\ S + \tfrac{1}{2}\ b\ (0.3\ n)\ (0.3\ C) = \tfrac{1}{2}\ b\ n\ C,$$

or $$A\ S = 0.455\ b\ n\ C.$$

The second condition is that the resisting moment of all these stresses shall equal the bending moment. Taking the center of moments at the neutral axis, this condition gives

$$A\ S\ (d - n) + 0.455\ b\ n\ C\ (0.2)\ n + \tfrac{1}{2}\ b\ n\ C\ (\tfrac{2}{3}\ n) = M.$$

To these two conditions of statics must be added another which states the experimental fact that changes of length in horizontal lines on the side of the beam are proportional to their distances from the neutral surface. Let $E_c$ be the modulus of elasticity of the concrete, and $E_s$ that of the steel; then the shortening of a unit length of the upper surface of the beam is $\frac{C}{E_c}$, and the elongation of a unit length of the steel is $\frac{S}{E_s}$, and these are proportional to the distances, $n$ and $d - n$. Accordingly,

$$\frac{C}{n\ E_c} = \frac{S}{(d - n)\ E_s}, \text{ or } \frac{d - n}{n} = \frac{S\ E_c}{C\ E_s}$$

is the third condition.

When a beam is to be designed, there are given its load and span, which determine the bending moment, $M$, the breadth, $b$, the moduli, $E_c$ and $E_s$, and the allowable unit stress, $C$, for the concrete; usually, the allowable unit stress, $S$, for the steel is also assumed. Then the solution of the three equations above written will give the values of $d$, $A$, and $n$.

This solution furnishes the following formulas for designing beams in which, for the sake of abbreviation, the ratio, $\frac{E_s}{E_c}$, is represented by the letter, $e$:

$$d^2 = \frac{2.92\ (e\ C + S)^2\ M}{(e\ C + 1.33\ S)\ e\ C^2\ b},\quad A = \frac{0.455\ e\ C^2}{(e\ C + S)\ S}\ b\ d.$$

The first of these formulas gives the depth, $d$, and hence, also, the section area, $b\ d$, of the concrete above the reinforcing rods, while the second gives the section area of the steel. The determination of these two quantities constitutes the main part of the design of the beam when the breadth, $b$, is given.

In using these formulas to design a reinforced beam, the constant, $e$, is approximately known for each class of concrete. For all kinds of steel, $E_s$ is closely 30 000 000 lb. per sq. in. For 1:2:4 concrete, $E_c$ is about 3 000 000 lb. per sq. in., and hence $e$ is about 10. For 1:3:6 concrete, $E_c$ is about 2 000 000 lb. per sq. in., and hence

Mr. Merriman.

$e$ is about 15. The unit stress, $C$, should be taken as high as allowable by the specifications, in order to make the depth, $d$, as small as possible. As for the unit stress, $S$, it is also often customary to take the highest allowable value for steel given in the specifications, but it will now be shown by a numerical example that this practice leads to uneconomical design.

Let it be required to design a reinforced beam of 1:3:6 concrete, for which $\frac{E_s}{E_c} = e = 15$, the highest allowable unit stresses to be 350 lb. per sq. in. for the concrete, and 17 500 lb. per sq. in. for the steel. Let the breadth of the beam be 12 in.; the span, 14 ft.; and the uniform load, 300 lb. per lin. ft., including the weight of the beam. Hence, the maximum bending moment, $M$, is 88 200 lb-in. Using these data, Table 6 gives the depth, $d$, computed from the first of the above formulas for five different values of $S$, after which the

TABLE 6.

| $S$, in pounds per square inch. | $d$, in inches. | $b\,d$, in square inches. | $A$, in square inches. | $b\,d + 60\,A$. | Relative cost. |
|---|---|---|---|---|---|
| 7 500 | 11.2 | 134.4 | 1.18 | 205.2 | 107.2 |
| 10 000 | 12.1 | 145.2 | 0.80 | 193.2 | 101.0 |
| 12 500 | 13.0 | 156.0 | 0.59 | 191.4 | 100.0 |
| 15 000 | 13.8 | 165.6 | 0.46 | 193.2 | 101.0 |
| 17 500 | 14.6 | 175.2 | 0.37 | 197.4 | 103.1 |

corresponding section areas, $b\,d$ and $A$, are found. Each of these beams have the strength required by the specifications to carry the given bending moment with the assigned degree of security, but their costs are different. If the cost of the steel is 60 times that of the concrete, then the sums, $b\,d + 60\,A$ will be proportional to the costs for the five cases, and it thus appears that the selection of 17 500 lb. per sq. in., as the tensile working stress in the steel, produces dimensions which make the cost 3.1% more than when the stress is taken at 12 500 lb. per sq. in. Hence it is plain that the selection of the value of $S$ is a matter of some importance.

Since both $b\,d$ and $A$ may be expressed in terms of $S$, it follows that the value of $S$ which renders the total cost a minimum is a problem of pure mathematics. Let $p$ be the ratio of the cost of one cubic unit of steel to that of one cubic unit of concrete; then the value of $S$ is to be obtained which renders $b\,d + p\,A$ a minimum, since $b\,d + p\,A$ is proportional to the total cost of that part of the beam above the center of the steel rods. For the sake of abbreviation, let $r$ represent the ratio, $\frac{S}{C}$, or $S = r\,C$, so that $S$

Mr. Merriman.

is known as soon as $r$ has been determined. Then the values of $b\ d$ and $A$ are:

$$b\ d = \frac{e + r}{\sqrt{e + 1.33\ r}} \sqrt{\frac{2.92\ M\ b}{e\ C}}$$

$$A = \frac{0.455\ e}{r\sqrt{e + 1.33\ r}} \sqrt{\frac{2.92\ M\ b}{e\ C}}.$$

Multiplying the expression for $A$ by $p$, differentiating the sum, $b\ d + p\ A$, with respect to $r$, equating the derivative to zero, and solving for $r$, gives

$$r = 1.17\ \sqrt{e\ p} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{I}$$

as the value of $r$ which is required in order that the cost of the beam shall be a minimum. Equation I is the first formula to be used in designing a reinforced concrete beam. For example, let $e = 10$ for 1:2:4 concrete, and $p = 60$; that is, let the cost of the steel per cubic unit be 60 times that of the concrete; then $r = 28.7$, or the unit stress, $S$, for the steel, must be 28.7 times as great as the unit stress, $C$, for the concrete.

After the ratio, $r$, has been ascertained from Equation I, the distance of the rods below the top of the beam is to be computed from

$$d = u\sqrt{\frac{M}{b\ C}}, \text{ in which } u = \frac{1.71\ (e + r)}{\sqrt{e\ (e + 1.33\ r)}} \quad \ldots\ldots\ldots \text{II}$$

and then the section area of the steel is found by

$$A = v\ b\ d, \text{ in which } v = \frac{0.455\ e}{r\ (e + r)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{III}$$

These three formulas enable the design of a reinforced concrete beam to be made which will carry the given bending moment, $M$, with the required degree of security, and also be more economical than one of any other dimensions. If the question of economy is not considered, Equations II and III will furnish values of $d$ and $A$ for any assumed unit stresses, $C$ and $S$, the ratio, $r$, to be used being the numerical value of $\frac{S}{C}$.

The distance of the neutral axis below the top of the beam can also be stated in terms of $r$, and also the ratio of the cost of the steel to that of the concrete, thus

$$\frac{n}{d} = \frac{e}{e + r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{IV}$$

and

$$\frac{p\ A}{b\ d} = p\ v \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{V}$$

Mr. Merriman. from which the neutral axis can be located, and the cost of the steel relative to that of the concrete computed.

Tables 7 and 8 show the relations between the different quantities more clearly than can be shown by formulas. These tables have been computed for seven values of $p$, ranging from 30 to 90, this quantity, $p$, being the ratio of the costs per cubic unit of steel and concrete. Column 2 shows the values of $r$ which must be used in order that the beam shall be of minimum cost, this ratio, $r$, being computed from Equation I, and being the ratio of the tensile unit stress, $S$, in the steel to the given compressive unit stress, $C$, on the upper surface of the concrete. Column 8 of Table 7 (for 1:2:4 concrete) gives values of $S$ in pounds per square inch when $C$ is taken as 500 lb. per sq. in., and Column 8 of Table 8 (for 1:3:6 concrete) gives values of $S$ when $C$ is taken as 350 lb. per sq. in.; these columns show that the unit stresses for the steel should decrease as steel becomes cheaper with respect to concrete.

Column 3 in Tables 7 and 8 gives values of $u$ to be used in computing the depth of the rods below the top of the beam from Equation II. Column 4 gives the values of $v$ for computing the section area of the steel from Equation III, and these numbers multiplied by 100 give the percentage of section area of the steel with respect to the concrete section area, $b\,d$; these columns show that the percentages of steel section to be used should increase as $p$ decreases, and also that 1:2:4 concrete requires a slightly larger percentage of steel than 1:3:6 concrete. Column 5 shows the position of the neutral axis when the beam is stressed under the given bending moment; on the average, this axis is about 26% of the depth below the top for 1:2:6 concrete, and a little lower for 1:3:6 concrete.

TABLE 7.—FOR 1:2:4 CONCRETE. $\frac{E_c}{E_s} = e = 10.$

| (1) Ratio, $p$ | (2) $r$ | (3) $u$ | (4) $v$ | (5) $\frac{n}{d}$ | (6) $\frac{p\,A}{b\,d}$ | (7) Approximate relative costs. | (8) Unit Stress, $S$, for $C$=500. |
|---|---|---|---|---|---|---|---|
| 90 | 35 | 3.2 | 0.0029 | 0.22 | 0.26 | 100 | 17 500 |
| 80 | 33 | 3.2 | 0.0032 | 0.23 | 0.26 | 98 | 16 500 |
| 70 | 31 | 3.1 | 0.0036 | 0.24 | 0.25 | 95 | 15 500 |
| 60 | 29 | 3.0 | 0.0041 | 0.26 | 0.25 | 92 | 14 500 |
| 50 | 26 | 2.9 | 0.0049 | 0.28 | 0.24 | 89 | 13 000 |
| 40 | 23 | 2.8 | 0.0060 | 0.30 | 0.24 | 85 | 11 500 |
| 30 | 20 | 2.7 | 0.0076 | 0.33 | 0.23 | 81 | 10 000 |

Column 6 gives the ratio of the cost of the steel to that of the concrete, as found from Equation V, and this is seen to be not far from 25 per cent. Column 7, headed "Approximate relative costs,"

contains numbers which apply to reinforced concrete beams when properly designed by the method here presented. In computing these numbers, the allowable compressive unit stress, $C$, has been taken at 500 lb. per sq. in. for 1:2:4 concrete and at 350 lb. per sq. in. for 1:3:6 concrete, and no allowance for difference in cost between these two classes of concrete or for the extra concrete below the reinforcing rods has been made. Under this supposition, the cost of reinforced beams is about 10 or 11% higher when the lower grade of concrete is used. Mr. Merriman.

TABLE 8.—FOR 1:3:6 CONCRETE. $\frac{E_s}{E_c} = e = 15$.

| (1) Ratio, $p$ | (2) $r$ | (3) $u$ | (4) $v$ | (5) $\frac{n}{d}$ | (6) $\frac{p\,A}{b\,d}$ | (7) Approximate relative costs. | (8) Unit Stress, $S$, for $C$=350. |
|---|---|---|---|---|---|---|---|
| 90 | 43 | 3.0 | 0.0027 | 0.26 | 0.24 | 110 | 15 100 |
| 80 | 41 | 3.0 | 0.0030 | 0.27 | 0.24 | 108 | 14 400 |
| 70 | 38 | 2.9 | 0.0034 | 0.28 | 0.24 | 105 | 13 300 |
| 60 | 35 | 2.8 | 0.0039 | 0.29 | 0.23 | 102 | 12 300 |
| 50 | 32 | 2.7 | 0.0045 | 0.32 | 0.22 | 99 | 11 200 |
| 40 | 29 | 2.6 | 0.0053 | 0.34 | 0.22 | 95 | 10 200 |
| 30 | 25 | 2.5 | 0.0069 | 0.38 | 0.21 | 90 | 8 800 |

In Equation II, for computing the depth, $a$, the letter, $C$, appears, so that this formula may be used for any specified compressive unit stress. This formula, of course, is only one of many that may be deduced for different assumptions regarding the tensile stresses below the neutral surface, each assumption giving a different expression for $u$. While the common assumption, that the concrete below the neutral surface offers no tensile resistance, leads to somewhat different formulas for $u$ and $v$, the numerical results obtained from them do not differ materially from those above given, as far as the values of $u$ and $v$ are concerned, although they give the position of the neutral axis somewhat higher. The writer has also worked out formulas and tables under the assumption that the tensile stresses in the concrete extend to the distance, $\frac{1}{2}n$, below the neutral axis, and finds that this gives the depths of beams and section areas of reinforcement about 3% greater than when no tension in the concrete is considered. Hence, neglect of the tensile resistances in the concrete is not on the side of safetly when beams are to be designed.

The writer's conclusions regarding the proper design of reinforced concrete beams are as follows:

1.—Formulas deduced from stress-strain curves of concrete tested to rupture in compression are irrational and unreliable for the design of beams.

Mr. Merriman.

2.—After the three fundamental equations have been written for any assumed stress-strain line, no further assumptions regarding the neutral axis or the lever arms of forces can be made without introducing contradictions which render the resulting formulas erroneous.

3.—When the unit stresses, $C$ and $S$, are assumed, the three fundamental equations determine the depth of the beam and the section area of the steel.

4.—The practice of using for the steel a tensile stress as high as one-half the elastic limit leads to uneconomical design, unless the cost of steel per cubic unit is greater than about 90 times the cost of 1:2:4 concrete or greater than about 100 times the cost of 1:3:6 concrete.

5.—The unit stress, $S$, to be used for the steel rods, should be such that the cost of the reinforced beam shall be a minimum, and this value may be ascertained from Equation I.

6.—When no precise information is at hand, regarding the relative costs of steel and concrete, the value of $r$, in Equations II and IV, may be taken at about 31 for 1:2:4 concrete and at about 35 for 1:3:6 concrete. This gives the section areas of the steel as 0.36 and 0.39% for these two classes of concrete.

7.—Steel with a high elastic limit should not be used for reinforcing rods if its price per pound is higher than that of structural medium steel.

8.—Some formulas and tables in use require percentages of steel section area to an extent which is not only unnecessary, but wasteful and extravagant. The highest steel section area which may be used for economical design is 0.75% of the concrete area above the rods, and this is only allowable when the cost of steel per cubic unit is as low as 30 times that of the concrete.

9.—For economical design, the cost of the steel is about 25% of that part of the concrete which lies above the centers of the reinforcing rods. The use of steel to an extent which renders its cost equal to the cost of the concrete section, $b\ d$, leads to uneconomical design.

10.—A high-class concrete, for which the modulus of elasticity is about 3 000 000 and the allowable compressive stress 500 lb. per sq. in., is more economical for reinforced beams than a concrete having a modulus of 2 000 000 and an allowable compressive stress of 350 lb. per sq. in., unless the cost of the latter concrete is at least 10% less than that of the former.

Mr. Perkins.

A. H. PERKINS, ASSOC. M. AM. SOC. C. E. (by letter).—That the moment equation for a reinforced concrete beam, as determined by any of the rational formulas for a given value of $t_s$, approximates very closely to a straight line, is a familiar fact to engineers work-

ing with curves such as those published in *Engineering News* by Mr. Schaub as long ago as April 30th, 1903. There the moment curve is plotted with $\frac{a}{d}$ as ordinates and $\frac{M}{b\,d^2}$ as abscissas. That the curve with $\frac{a}{d}$ constant and $t_s$ and $\frac{M}{b\,d^2}$ the varying elements also approximates a straight line, is new, and the resulting general equation is extremely simple. There is a general feeling among engineers, however, that what is wanted is not so much accurate formulas, although they are desirable, as accurate constants for use in formulas. Knowledge of proper values of $E_c$ could hardly be in a more chaotic condition, and an extension of the knowledge of the proper percentages of reinforcement to be used with various mixtures would be received with pleasure by most engineers. However, even though the cart has been obtained before the horse, the possession of the cart is cause for congratulation. Mr. Perkins.

That 0.8 represents the "reliability factor" of the strength of concrete, as compared with steel at its elastic limit, will be questioned by many engineers. The elastic limit of concrete is not more than three-fourths of its ultimate strength for the leaner mixtures, such as 1:3:6. This is shown clearly by the data presented by Professor Hatt* and by the Talbot experiments. With the richer mixtures, more common in reinforced construction, the elastic limit is probably a somewhat greater percentage of the ultimate strength. In addition, there is the variation in the strength of the same grade of concrete. It would seem, therefore, that it would have been better to have left the factor, 0.8, out of the equations, permitting the user to suit himself or the conditions in choosing the corresponding factor.

The writer observes that the author finds by his analysis the same position for the centroid of pressure that was obtained by Professor Talbot by analysis ($= \frac{7}{11}$ of $y$, above the neutral axis) at the time he reported his now classical set of experiments.

However completely a beam may be reinforced, it will fail as soon as the elastic limit of the metal is passed unless the percentage of reinforcement is below that which develops the full strength of the concrete at the elastic limit of the metal, for the reason that when the elastic limit of the metal is passed the neutral axis rises rapidly, and the unit stress in the upper fiber of the concrete increases. Hence, designing a beam that will not go to pieces when the elastic limit of the metal is passed, involves under-reinforcement. Web reinforcement is necessary, of course, under certain conditions, and perhaps desirable under nearly all conditions; however, it will not produce impossibilities, and should not be

* *Transactions*, Am. Soc. C. E., Vol. LIV, Part E, pp. 587 *et seq.*

Mr. Perkins. expected to produce a beam that will not go to pieces soon after the elastic limit of the metal is reached, if the percentages of reinforcement recommended by the author are used with ordinary mixtures. The elongation of 30 000-lb. elastic-limit steel at the elastic limit will be 0.1%, and between the elastic limit and the ultimate it will be about 25 per cent. For steel of 50 000-lb. elastic limit, the elongation at the elastic limit is 0.17% and at the ultimate 15 per cent. Now throw the author's Equation 4 into the form

$$k = \frac{n f c}{n f c + t_s}, \quad \text{where} \quad k = \frac{y_1}{d}, \quad \text{and} \quad n = \frac{E_s}{E_c}.$$

This is true for any shape of the stress-strain curve within the elastic limits of the materials, and may be used to find $k$ at the ultimate by putting for $t_s$, 250 times $t_s$ for steel of 30 000-lb. elastic limit, or 88 for steel of 50 000-lb. elastic limit ($t_s$ remaining the stress at the elastic limit). It is evident that these values will give such attenuated values for $k$ that the amount of reinforcement permissible would be "the ghost of a departed quantity."

TABLE 9.

| $t_s$. | $k$. | $\frac{a}{d}$. | $F$. | $f_s(6M_c)$. | $\frac{E_s}{E_c}$. | Mixture. | $\frac{M}{bd^2}$. |
|---|---|---|---|---|---|---|---|
| 30 000 | 0.4 | 0.0152 | 2 000 | 3 000 | 10 | 1 : 2 : 4 | 408 |
| | 0.333 | 0.0095 | 1 500 | 2 500 | 10 | 1 . 3 : 6 | 251 |
| 40 000 | 0.333 | 0.0095 | 2 000 | 3 000 | 10 | 1 : 2 : 4 | 339 |
| | 0.273 | 0.0058 | 1 500 | 2 500 | 10 | 1 : 3 : 6 | 211 |
| 50 000 | 0.286 | 0.0065 | 2 000 | 3 000 | 10 | 1 : 2 : 4 | 293 |
| | 0.231 | 0.0040 | 1 500 | 2 500 | 10 | 1 : 3 : 6 | 181 |
| 60 000 | 0.250 | 0.0048 | 2 000 | 3 000 | 10 | 1 : 2 : 4 | 260 |
| | 0.200 | 0.0029 | 1 500 | 2 500 | 10 | 1 : 3 : 6 | 159 |

This leads directly to the vexed question of factors of safety. If the concrete be reinforced up to the point where the steel reaches the elastic limit when the upper fiber of the concrete is at its ultimate, then the factor of safety of the concrete is only half that of the steel, a condition the reverse of what it should be, and that is manifestly a waste of metal. On the other hand, if $\frac{a}{d}$ be taken below the above-mentioned value, the beam goes to pieces before the full ultimate stress in the concrete is used. In other words, there is no way to utilize the factor of safety of 2 that steel has between the elastic limit and the ultimate strength. Of the two horns of the dilemma, it is clear to the writer that stressing the concrete below its ultimate is by far the short horn, and the better engineering.

The writer, therefore, would use, in the author's formulas, the values of $\frac{a}{d}$ and $F$ shown in Table 9 modified by leaving out the factor, 0.8. Mr. Perkins.

Perhaps a larger value of $\frac{E_s}{E_c}$, say 12, should be taken for the 1:3:6 mixture. This would make the resulting values of $\frac{a}{d}$ slightly larger. To the $\frac{M}{b\,d^2}$ in Table 9 the writer would apply a factor of safety of at least 2½ for dead loads.

LANGDON PEARSE, JUN. AM. SOC. C. E. (by letter).—The writer has read Captain Sewell's interesting paper and the discussion thereon with much pleasure. He would like to add a few notes on the stress-strain curve of concrete in compression, based on tests made for the Boston Elevated Railway.* Mr. Pearse.

These notes, made in connection with a thesis at the Massachusetts Institute of Technology in 1902, refer only to the 1:2:4 mixture. Plots of the stresses and strains were made on logarithmic paper, first the inelastic strains, that is, the strains produced by the first loadings, and second the elastic strains, that is the first strain minus the permanent set. Logarithmic plotting paper was used because of the well-known property that the logarithms of points on a parabola lie in a straight line.

An examination of the inelastic strain plots showed that in few cases could one straight line be passed through all the points plotted, whereas in many cases two straight lines at a considerable angle, and, in one or two cases, three straight lines could. This would mean that two or more parabolas might represent the curves. The elastic strains followed the straight lines more closely, so that one line was fairly representative for each set of observations.

In both cases the constants were derived for the range of stress from 300 lb. per sq. in. up to the ultimate strength, unless otherwise noted, assuming that the probable curve was $y^n = p\,x$,

where $y$ = the stress, in pounds per square inch;

$x$ = the change of length or strain, in inches per inch.

$n$ and $p$ are the constants to be derived.

The values used in the computations are given in Tables 10 and 11. The columns headed $y_1$ and $x_1$ give the low point, $y_2$ and $x_2$ the high point from which the constants, $n$ and $p$, were calculated. The columns headed $y_3$ and $x_3$, and $y_4$ and $x_4$, give the points from which the values of $n_1$ and $p_1$ were determined. Tables 10 and 11, respectively, give the inelastic and elastic constants.

Using $y^n = p\,x$ as the stress-strain equation, according to the

* "Tests of Metals," U. S. War Dept., 1899.

TABLE 10.—INELASTIC STRESS-STRAIN CURVE FOR 1 : 2 : 4 CONCRETE.

| Cement. | Time of Set. | $y_1$ | $x_1$ | $y_2$ | $x_2$ | $n$ | $p$ | $y_3$ | $x_3$ | $y_4$ | $x_4$ | $n_1$ | $p_1$ | Breaking strength, in pounds per square inch. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alpha..... | 7 d. | 190 | 0.0001 | 300 | 0.0006 | 3.195 | $2.043\times10^{13}$ | 300 | 0.00062 | 700 | 0.0044 | 2.313 | $8.638\times10^{8}$ | 962 | |
| Alpha..... | 1 mo. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 590 | Points too scattered to draw curves. |
| Alpha..... | 3 mo. | 500 | 0.0001 | 2 300 | 0.001 | 1.484 | $1.011\times10^{8}$ | ..... | ..... | ..... | ..... | ..... | ..... | 3 226 | |
| Alpha..... | 6 mo. | 490 | 0.0001 | 2 400 | 0.001 | 1.285 | $9.207\times10^{7}$ | ..... | ..... | ..... | ..... | ..... | ..... | 4 847 | |
| Atlas..... | 8 d. | 350 | 0.0001 | 1 000 | 0.001 | 2.193 | $3.802\times10^{9}$ | 1 000 | 0.001 | 1 600 | 0.0051 | 3.469 | $5.22\times10^{13}$ | 1 695 | |
| Atlas..... | 1 mo. | 420 | 0.0001 | 1 800 | 0.001 | 1.582 | $1.414\times10^{8}$ | ..... | ..... | ..... | ..... | ..... | ..... | 2 373 | Curve breaks just below 1800. |
| Atlas..... | 3 mo. | 450 | 0.0001 | 2 100 | 0.001 | 1.495 | $9.236\times10^{7}$ | 2 100 | 0.001 | 2 900 | 0.004 | 4.294 | $1.845\times10^{17}$ | 2 918 | |
| Atlas..... | 6 mo. | 490 | 0.0001 | 2 060 | 0.001 | 1.405 | $4.57\times10^{7}$ | 2 400 | 0.0012 | 2 900 | 0.004 | 6.362 | $2.66\times10^{24}$ | 4 000 | |
| Germania. | 7 d. | 370 | 0.0001 | 1 240 | 0.001 | 1.904 | $7.759\times10^{8}$ | ..... | ..... | ..... | ..... | ..... | ..... | 2 400 | |
| Germania. | 1 mo. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 933 | Micrometer broke. |
| Germania. | 3 mo. | 500 | 0.0001 | 2 000 | 0.001 | 1.661 | $3.04\times10^{8}$ | ..... | ..... | ..... | ..... | ..... | ..... | 3 157 | |
| Germania. | 6 mo. | 469 | 0.0001 | 1 940 | 0.001 | 1.600 | $1.82\times10^{8}$ | 1 940 | 0.001 | 3 000 | 0.0032 | 2.668 | $5.93\times10^{11}$ | 3 309 | |
| Alsen..... | 10 d. | 335 | 0.0001 | 1 180 | 0.001 | 1.828 | $4.145\times10^{8}$ | 1 180 | 0.001 | 1 840 | 0.0043 | 3.233 | $1.32\times10^{13}$ | 1 862 | |
| Alsen..... | 1 mo. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 2 373 | Curve made of more than 2 parabolas. |
| Alsen..... | 3 mo. | 355 | 0.0001 | 1 560 | 0.001 | 1.555 | $9.262\times10^{7}$ | ..... | ..... | ..... | ..... | ..... | ..... | 2 600 | Curve drops near end. |
| Alsen..... | 6 mo. | 420 | 0.0001 | 2 260 | 0.001 | 1.368 | $3.881\times10^{7}$ | ..... | ..... | ..... | ..... | ..... | ..... | 3 800 | Curve drops. |
| Saylor's... | 9 d. | 184 | 0.0001 | 700 | 0.001 | 1.723 | $8.00\times10^{7}$ | ..... | ..... | ..... | ..... | ..... | ..... | 1 944 | |
| Saylor's... | 1 mo. | 430 | 0.0001 | 1 300 | 0.001 | 2.081 | $3.023\times10^{9}$ | 1 300 | 0.001 | 2 100 | 0.006 | 3.736 | $4.296\times10^{14}$ | 2 119 | |
| Saylor's... | 3 mo. | 440 | 0.0001 | 1 800 | 0.001 | 1.635 | $2.093\times10^{8}$ | 1 800 | 0.001 | 2 600 | 0.004 | 2.770 | $1.866\times10^{15}$ | 2 778 | |
| Saylor's... | 6 mo. | 500 | 0.0001 | 2 300 | 0.001 | 1.509 | $1.181\times10^{8}$ | 2 400 | 0.0011 | 4 200 | 0.0045 | 2.584 | $5.10\times10^{11}$ | 3 959 | |

Mr. Pearse.

definition of the modulus of elasticity, $E$, as the ratio of the change of stress to the change of strain, then Mr. Pearse.

$$E = \frac{d\,y}{d\,x} = \frac{p}{n\,y^{n-1}}.$$

This is the slope of the curve at the point, $x_1$ $y$. Now if $y = 0$, $E = \infty$. This is clearly untrue, although for small values of stress the real strain is not known. It is probable that concrete is elastic, in the ordinary sense, up to 200 or 300 lb. per sq. in., and even up to 500 lb. per sq. in., in some cases, though permanent set is usually measured below that stress. The correct expression for the stress-strain curve in compression would seem to be a parabola with the vertex at zero, but with its axes slightly revolved so that the slope is finite at the origin, or else a combination of parabola and straight line—the straight line extending to the point at which permanent set is noted, the parabola from there to the point of ultimate strength.

TABLE 11.—ELASTIC STRESS-STRAIN CURVE FOR 1 : 2 : 4 CONCRETE.

| Cement. | Time of set. | $y_1$ | $x_1$ | $y_2$ | $x_2$ | $n$ | $p$ | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Alpha..... | 7 d. | 234 | 0.0001 | 820 | 0.0008 | 1.667 | 91 650 000 | |
| Alpha..... | 1 mo. | ..... | ..... | ..... | ..... | ..... | ..... | |
| Alpha..... | 3 mo. | 564 | 0.0001 | 2 840 | 0.0010 | 1.425 | 88 040 000 | |
| Alpha..... | 6 mo. | 422 | 0.0001 | 3 100 | 0.0010 | 1.130 | 9 310 000 | |
| Atlas..... | 8 d. | 395 | 0.0001 | 1 520 | 0.0010 | 1.708 | 273 300 000 | |
| Atlas..... | 1 mo. | 425 | 0.0001 | 1 690 | 0.0010 | 1.668 | 242 000 000 | |
| Atlas..... | 3 mo. | 515 | 0.0001 | 2 390 | 0.0010 | 1.500 | 116 800 000 | |
| Atlas..... | 6 mo. | 442 | 0.0001 | 2 640 | 0.0010 | 1.289 | 25 580 000 | |
| Germania... | 7 d. | 369 | 0.0001 | 1 820 | 0.0010 | 1.443 | 50 540 000 | |
| Germania... | 1 mo. | ..... | ..... | ..... | ..... | ..... | ..... | Micrometer broke. |
| Germania... | 3 mo. | 468 | 0.0001 | 2 600 | 0.0010 | 1.343 | 38 540 000 | |
| Germania... | 6 mo. | 525 | 0.0001 | 1 840 | 0.0006 | 1.428 | 76 900 000 | Curve flattens at top. |
| Alsen..... | 10 d. | 390 | 0.0001 | 1 800 | 0.0010 | 1.505 | 79 650 000 | |
| Alsen..... | 1 mo. | 420 | 0.0001 | 2 090 | 0.0010 | 1.435 | 58 100 000 | |
| Alsen..... | 3 mo. | 420 | 0.0001 | 1 630 | 0.0007 | 1.435 | 58 130 000 | Curve flattens above this. |
| Alsen..... | 6 mo. | 570 | 0.0001 | 2 430 | 0.0008 | 1.434 | 89 600 000 | |
| Saylor's... | 9 d. | 298 | 0.0001 | 1 560 | 0.0010 | 1.359 | 27 650 000 | |
| Saylor's.... | 1 mo. | 450 | 0.0001 | 1 800 | 0.0010 | 1.661 | 255 300 000 | |
| Saylor's.... | 3 mo. | 455 | 0.0001 | 2 190 | 0.0010 | 1.465 | 78 560 000 | Curve flattens at top. |
| Saylor's.... | 6 mo. | 580 | 0.0001 | 1 900 | 0.0005 | 1.356 | 56 020 000 | |

For all practical purposes, the writer favors the formulas based on a straight-line stress-strain curve, using constants based on working values of the fiber stresses in steel and concrete, neglecting the concrete in tension.

C. B. WING, ASSOC. M. AM. SOC. C. E. (by letter).—In a recent paper before the Canadian Society of Civil Engineers, Henry Goldmark, M. Am. Soc. C. E., has stated that most of the formulas proposed for the design of reinforced concrete are based on the Mr. Wing.

Mr. Wing. common theory of flexure of homogeneous materials, with modifications due to the composite nature of the beam and physical properties of concrete differing from those of steel.

A more accurate statement would be that proposed formulas may be divided into two classes, one class for which Mr. Goldmark's statement is true, and another class in which the modifications and assumptions are of such a character that all semblance to the ordinary theory of flexure is lost, and the resulting formulas are purely empirical.

The formula proposed by the author is of this latter class; and, for low percentages of reinforcement, with material of low elastic limit, will be found to give ultimate strengths agreeing closely with the results of tests.

The range of application of the formula, however, is limited, as will be shown later, and in inexperienced hands may give extremely dangerous results.

The stress-strain diagram of a reinforced concrete beam shows two critical points: the point of failure of the concrete in tension, and the elastic limit of the steel.

These points may be compared with the elastic limit and the point of rupture of the stress-strain diagram of steel in tension, with the difference that, in the case of steel, stresses beyond the elastic limit cause permanent deformation, while, in the case of reinforced concrete, stresses beyond the tensile strength of the concrete only lead to the opening up of cracks which are closed on the removal of the load if the elastic limit of the metal has not been exceeded.

The whole question of proper methods of designing reinforced concrete would seem to hinge on this one point, that is, to what extent it is safe to allow tensile cracks to form in reinforced concrete beams.

This point can only be settled satisfactorily by tests for the effect of corrosion and repeated stress on reinforced concrete beams in which such cracks have formed.

Until such tests have been made, conservative design would require that the maximum stresses in the outer fiber of reinforced concrete beams be kept within the limits of the ultimate tensile strength of the concrete, say 300 lb. per sq. in. for a fair quality of concrete.

If this principle is accepted, the best type of formula to use is one based on the ordinary theory of flexure.

At present the design of beams by such formulas is comparable to the condition that would exist if all tables of moments of inertia and properties of steel beams were to be destroyed.

However, by adopting a proper notation, and preparing tables,

Mr. Wing.

it is possible to solve theoretical composite beam formulas with the same ease that solutions of formulas for homogeneous beams are obtained.

Such theoretical formulas can be shown to give results agreeing closely with the results of tests, both at the point of failure of the concrete in tension and at the point at which the elastic limit of the steel is reached.

This being the case, there would seem to be no justification for adopting a formula theoretically open to criticism, of limited application, and which, in inexperienced hands, would give dangerous results.

Table 12 has been prepared in order to show the difference in designs obtained by using the author's formulas with $t_s = 16\,000$ lb. per sq. in., and by using a formula based on the ordinary theory of flexure limiting the tensile stress in the concrete to 300 lb. per sq. in.

The beams in Table 12 have been calculated as having a resisting moment of 120 000 in-lb. The beams calculated by the ordinary flexure formulas are square, with the center of the steel reinforcement 1 in. from the lower surface of the concrete. The beams calculated by the author's formula are square, above the center of the steel, and have 1 in. added to the depth to provide a protective coating for the steel.

The cost of concrete was assumed at 20 cents per cu. ft., and the cost of steel at 3 cents per lb.

The author states that "the actual working stress in the concrete would seem to be of secondary importance as long as the factor of safety is assured." It is difficult to understand how the factor of safety is assured when beams designed by the author's formula show probable values of the compressive stress in the concrete as given in Table 12. These values have been calculated by the ordinary theory of flexure, neglecting the tension in the concrete, and may be higher than the stresses actually existing, but beams calculated by such formulas are on the side of safety.

The author, in justification of an empirical formula, speaks of the plate girder as a case in which the designer departs from the ordinary theory of flexure, but fails to state that such departure leads to the design of heavier beams than would be required by the ordinary theory of flexure.

It is to be regretted that the author's proposed formula and other similar formulas do not in all cases in like manner give results departing from the ordinary theory of flexure on the side of safety. It is safe to say that, if such were the case, technical literature would be but little burdened with discussions of the true form of the stress-strain curve for concrete in compression, and the old-fashioned Hooke's Law would be considered near enough for practical purposes.

Mr. Wing.

The portion of the paper devoted to the determination of the economic percentage of reinforcement depends entirely upon the acceptance of the proposed formula. If that is not accepted, the whole argument is without foundation, and that the acceptance of this formula may lead to dangerous designs is indicated by the results given in Table 12, which show that beams designed by the ordinary flexure formulas will increase in cost with the percentage of reinforcement.

For economy, the percentage of reinforcement, therefore, should be as small as good practice will warrant, and is not a subject for theoretical determination.

TABLE 12.

| Ordinary Flexure Formula. | | | | | Author's Formula. | | |
|---|---|---|---|---|---|---|---|
| Percentage of reinforcement. | Side of square beam, in inches. | Cost per foot, in cents. | Probable maximum stresses per square inch, if concrete fails in tension. | | Depth of beam; width 1 in. less. | Cost per foot, in cents. | Probable compression in concrete per square inch. |
| | | | Tension in steel. | Compression in concrete. | | | |
| ½ | 12.8 | 31.0 | 14 300 | 530 | 12.4 | 26.1 | 640 |
| ¾ | 12.6 | 33.6 | 10 000 | 490 | 11.0 | 22.8 | 800 |
| 1.0 | 12.3 | 36.1 | 8 100 | 470 | 10.1 | 21.1 | 1 040 |
| 1¼ | 12.1 | 38.3 | 6 800 | 460 | 9.4 | 19.8 | 1 130 |
| 1½ | 11.9 | 40.5 | 6 000 | 460 | 8.9 | 19.2 | 1 280 |
| 1¾ | 11.7 | 42.6 | 5 500 | 460 | 8.5 | 18.9 | 1 440 |
| 2.0 | 11.5 | 44.7 | 5 000 | 460 | 8.2 | 18.6 | 1 560 |

Captain Sewell.

JOHN S. SEWELL, M. AM. SOC. C. E.* (by letter).—After reading the discussion which has been brought out by his paper, the writer feels that its main object, which was to arouse a greater interest in certain points pertaining to the design of reinforced concrete, has been largely accomplished. He desires to express his gratitude for the kindly expressions of appreciation on the part of so many of those taking part in the discussion.

In order to set at rest the doubts apparently existing in the minds of some, he desires to say that he claims no originality for anything fundamental in any part of the formulas discussed or proposed by himself. Even the treatment of web stresses, which is different from any he has seen elsewhere, could not be called original, in the fullest sense of the word, and it may not be so, in any sense. The question of originality, however, is entirely secondary to that of correctness. The writer, in common with many other engineers, has studied such data as he had available, and, in the light of such study and his own experience, has deduced conclusions in which he has great personal confidence. But it is

*Captain, Corps of Engineers, U. S. Army.

realized that these conclusions are rather matters of opinion than thoroughly demonstrated facts, and it is hoped that the extensive series of tests about to be inaugurated under the auspices of this and other societies may cover the ground in so thorough a manner as to leave no room for further doubt or discussion. Captain Sewell.

The point raised by Mr. Jonson, in reference to taking the depth of the horizontal reinforcement below the top of the beam as a basis for the shear computation, is well taken. Referring to page 650,* and to Fig. 4, the depth should be $h\ d$, instead of $d$. The writer had intended to correct this error, but will content himself by acknowledging the accuracy of Mr. Jonson's criticism. It should, perhaps, be further explained, that Fig. 4 and its accompanying text constituted a demonstration of the writer's method of treating the web stresses, rather than a statement of the method itself. As a matter of fact, when the writer uses diagonal web members, if $a$ be the area of the horizontal reinforcement, the aggregate section of the web members in one-half of the beam is taken as $\frac{1}{2}\ a\ \sqrt{2}$; if vertical web members are used, their aggregate area in one-half of the beam is taken as $a$; neither of these expressions would be quite correct if the depth were taken as $d$; nor would they result from an actual determination of stresses in a multiple-intersection truss with a finite number of web systems. The greater the number of web systems, the more nearly does the aggregate of the tensile web stresses approach equality with the aggregate of the compressive stresses; and, in a solid beam, they become equal; under these conditions, the writer's expressions for the aggregate section of web members are correct. If diagonal members are used, the length of each member is equal to $d\sqrt{2}$. The total volume of the members in one-half of the beam is then equal to $a\ d$. The same expression holds for the volume of the vertical members, so that the total weight of the web reinforcement is the same in the two cases, assuming the web members to extend to the top of the beam, in either case. In any case, the number of web members necessary to make up the aggregate section is determined by dividing the aggregate by the area of one member. Their spacing is determined in much the same manner as that used for the rivet spacing for a plate girder.

Replying to Mr. Watson: the unreasonable and illogical requirements of many building laws constitute one of the reasons for writing this paper. These laws often, on the one hand, put reinforced concrete at an unfair disadvantage, and, on the other, open up the way to very real dangers in design. The writer is also opposed to the use of high-carbon steel, or any steel with an elastic

* *Proceedings*, Am. Soc. C. E., for December, 1905.

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limit exceeding, say, 40 000 to 45 000 lb. per sq. in. If the modulus of elasticity could be increased with the elastic limit, the matter might be different; but, as it is, the greater strength of the steel with a high elastic limit can be utilized only by permitting deformation beyond a reasonable limit, and by permitting the neutral axis to rise so high in the beam that the economy of the greater stress in the steel is largely lost, because of the greater quantity of concrete needed to counterbalance the steel stresses. The strength of the steel with a high elastic limit is also likely to be seriously impaired in a fire, which is in itself a sufficient reason for using soft or medium steel in fire-resisting structures, not to mention the other very valid objections to high-carbon steel urged by Mr. Watson.

Vertical stirrups, merely passing under the main bars, cannot possibly transmit any tensile stress into those bars, for no force has a component at right angles to itself; nor can such stirrups afford an abutment for the diagonal compressive stresses in the concrete, except in so far as the concrete itself serves as an anchorage for them. As one cannot lift himself by his own boot straps, it is difficult to know how the stirrups described by Mr. Watson can assist in any way except by reinforcing the concrete against local failure, and thus holding adhesion up to its full value. This seems to be only a partial solution of the real problem.

Replying to Mr. Noble: the writer expects that well-conducted experiments will prove quite conclusively that percentages of reinforcement, considerably greater than those deduced from his own equations, can be safely used. The writer, in assuming his constants, tried to keep well within safe limits, and the discussion indicates that in this, at least, he was successful.

The great value of the adhesion, and of the shearing strength in concrete is not denied; but both are subject to at least as many uncertainties as the tensile strength, and the writer prefers to let them all go into the indeterminate part of the factor of safety—especially in structures likely to be damaged by fire.

Mr. Kreuger's comments, concerning the width of flange in T-beams, touch upon a very interesting point—one which, as it is treated in such building laws as those of New York City, opens up the way to some decidedly dangerous designs. The writer's width of flange was deduced from a discussion based on the shearing strength of concrete. While he now disregards this, as far as possible, the width of the rib, in a T-beam, results from considerations affecting the transfer of the tensile stress from the steel into the compressed part of the concrete; the questions of how much stress can be distributed into the slab on either side, and how far it must go before being absorbed, are not usually easy to determine. But, the length of the span, and all other real factors, enter, in-

directly, into the design of the rib, and a width three times as great as the width of the rib will usually be found quite safe and sufficient for the flange, except in the rare case where very heavy beams are spaced very closely together, with a very thin floor slab on top of them. In that case, the thickness of the flange would seem to be the correct basis for determining its width. The writer sees no objection to making it the basis in all cases. Captain Sewell.

Referring to Mr. Dana's comments on the writer's reasons for using attached web members because of the facility for repairing beams damaged by fire, it should be pointed out that exposure of steel members results from the spalling of the concrete, rather than from complete dehydration of the cement. The Baltimore fire, and many fire tests have demonstrated that the steel itself is often exposed, without suffering serious damage; it is to be presumed that the fire is usually about exhausted, in such cases, before the concrete finally comes off. But, for fire-resisting structures, the writer is opposed to steel of very high elastic limit, because of the very danger pointed out by Mr. Dana. If every beam that has its main rods exposed has to be torn out and rebuilt, reinforced concrete will not long be in favor with underwriters, for the salvage will hardly be greater than in the case of a timber structure. While it is a slight digression, it might be suggested that if every fire test of a proposed type of fire-resisting construction had been carried far enough to determine correctly the salvage after the fire, a good many erroneous conclusions on the subject of fire-proof buildings would have been avoided.

Mr. Turner seems not to have comprehended the real intent of the paper at all; he has set up a straw man and knocked him over, but it is not clear that this has any very direct bearing on the questions discussed. However, an attempt will be made to answer Mr. Turner's objections.

There is decided room for differences of opinion as to whether the type of construction shown by Mr. Turner in Figs. 8 and 9 will be more economical than an equivalent one, using ribs or beams, and a thinner slab. Ingenuity in designing the centering for the ribs might upset Mr. Turner's estimates of cost, without the slightest trouble.

The writer is quite well aware, however, of the extra cost of centering for ribs, and, for that reason, has often preferred and used a plain slab rather than a ribbed construction, even though the slab was quite heavy. But he still maintains that for extensive floors, and heavy loads, there is economy in a ribbed construction; moreover, the conditions of the problem do fix the spacing of ribs within rather narrow limits, as a rule. However, it was not the purpose to treat this question by the laws of maxima and minima, for the

Captain Sewell.

reason that the writer has not been able to find any principles governing it in such a way that the skill of a good foreman or designer, expended on the centering, might not be the vital factor in deciding the question, after all. But, assuming the spacing of beams and girders to be fixed, there are such questions as the most economical design of slab and the most economical design of beam, and it was these questions that the writer undertook to discuss—that is, the economical sections of slabs and beams, the bending moments in the two cases being known. In the structure, as a whole, there may be broader questions of economy than in its individual members; but there is an economical design for each of them, and it should not be neglected, for it has a very vital bearing on the whole of the broader question.

Mr. Turner seems also to have missed the essence of the discussion of minimum cost for individual members. If concrete is very cheap, and steel very dear, it may easily happen that the cheapest beam, to carry a given load, may be one in which the concrete is not stressed to anything like its safe limit. On the other hand, it might be possible for concrete to be so expensive, and steel so cheap, that the least expensive beam would be one in which the steel was stressed very lightly, and the concrete to the full limit. Under such conditions, the paper might have to be revised; but, if such conditions existed, it would probably be cheaper to use structural steel; therefore no attempt was made to discuss the question under such assumptions. It is somewhat surprising, however, that this point has not been raised in the discussion of the paper.

As far as the utility of the writer's economic theory is concerned, he has found it useful in his own work, and detailed estimates based on actual designs have proven it correct within its own limits. To make its utility perfectly clear, one might suppose a piece of construction work in which the excavation for footings, etc., yields an ideal material for concrete; there may be nearby a cement plant, from which cement can be obtained at mill prices. Probably the concrete, apart from centering, in such cases, would cost not more than $2.25 per cu. yd. Suppose the cost of steel delivered at the site is very high, say, 5 cents per lb. It does not require a mathematical discussion to show that under such circumstances, economy demands deep beams and slabs, and light reinforcement; but there is an economical limit, and the writer's theory enables the engineer to determine it at once. It would seem that this is worth while, at any rate.

The writer is unable to see the peculiar value of his economical theory to any commercial interest, but as he has never been engaged in any commercial enterprise, there may be possibilities in it which his lack of experience prevents him from seeing.

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Mr. Turner lays great stress upon the tests of certain floor slabs, presumably of his own design. Their behavior cannot be explained by any rational formula based on flexure, for the simple reason that they were never subjected to such a bending moment as Mr. Turner figures as due to the load. The secret of their great carrying power is the absolutely unyielding abutments afforded on all sides by the remainder of the floor construction. The writer has had exactly parallel cases in his own work, and has seen them in the work of others. If Mr. Turner had selected an outer panel, next to the wall, for his test, he might have obtained a very different result; or, if he had cut his test panel loose from the neighboring panels—or, if he had tested an entire floor to the extent illustrated in his photographs—it is quite certain that the results would not have been inexplicable, even by the theory of flexure. As a matter of fact, in the panel which was about 16 ft. square, the shearing stress around the outer edges appears to have been not more than 60 lb. per sq. in.—not a dangerous value for really good concrete. The panel, acting as a flat dome, was able to carry the load with stresses probably not exceeding 2 000 lb. per sq. in. The reinforcement below, and the load above, prevented local deformation or buckling. It is very doubtful, however, whether two or three times the load of 900 lb. per sq. ft. would have been required to produce collapse; in fact, the load, as it was, was rather dangerously close to the limit, and, also, under such conditions, collapse is almost sure to be sudden and without appreciable deflection or warning of any kind. Mr. Turner would have added much to the knowledge on the subject if he had carried the test to destruction.

The writer's opinions on the subject are derived from the study of one or two actual failures, where conditions were not entirely unlike those shown in Mr. Turner's photograph; but he will be very glad to revise them, if Mr. Turner, by a test or tests carried to destruction, can prove them wrong.

The writer's explanation of the carrying power of the slab is not materially different from that indicated by Mr. Turner himself, in Fig. 11. Both require unyielding abutments; the slightest movement in these would develop the bending stresses at once, and even Mr. Turner will hardly claim that his slabs would have resisted, as beams, the bending moments due to his loads. The writer has used slabs reinforced both ways by plain round rods, and supported all around by beams, as in Mr. Turner's tests; and, where he felt sure of unyielding abutments, he has reduced the bending moments for which the slab was designed, to an extent that he would not recommend for ordinary practice. As Mr. Turner does not disclose his own methods, he may feel the same way about them; but, any one familar with the carrying power of a flat Guastavino dome need feel no surprise at the carrying power of

Captain Sewell.

Mr. Turner's slabs, whatever may be the true explanation. It might also be suggested that steel beams tightly framed in between unyielding abutments, would carry loads as much in excess of their capacities, as based on the theory of flexure, as did Mr. Turner's floor slabs. The writer has often thought that, in insisting upon statically determinate conditions, American designers of steel structures have sacrificed a great deal of reserve strength, especially against local overloads, as well as a very desirable rigidity and a perfectly justifiable economy.

To the writer's mind, however, Mr. Turner's slabs were in a dangerous state of unstable equilibrium under the test loads; a very little fire, or a sudden shock, applied in addition to the loads, would probably have caused collapse of a very sudden and destructive nature. While the writer knows but little of the floor in the building of the Farwell, Ozmun and Kirk Company, to which Mr. Turner refers, he thinks that, in the absence of tests to destruction in both cases, final conclusions and invidious comparisons are not justified.

It is noted that Mr. Turner does not state the working loads for which the floors described by him were designed, nor does he reveal the methods used—all of which would have been much appreciated.

The basis of the writer's belief in attached web members is the very satisfactory practical results shown in their use. Professor Talbot's tests, referred to by Mr. Turner, were hardly fair, because the web members were not long enough, and they were not spaced according to the variation in stresses. The writer used the Warren truss as the analogy, because tests show that the web stresses in reinforced concrete, or any other solid, beam, are inclined at an angle of about 45°, and, as long as the beam is solid, they cannot be made to take any other direction; vertical web members can take up the vertical components of the tensile web stresses, but they cannot change the direction of the resultant stress. As for Mr. Turner's suggestions of an inverted bowstring or a Bollman truss, he would find some difficulty in anchoring his tensile members at the ends. In his application of the writer's economic theory to a plate girder made of two kinds of steel, he deduces results which would be correct if, in steel, it were cheaper to let the unit web stresses vary; but, as a matter of fact, the conditions are entirely different, and the unit stress in the web would be the constant—not the thickness of the web. This application to an impossible—or at least highly improbable—plate girder, is merely another straw man demolished.

The suggestion that the lower part of a beam might be made of clinker concrete was not made with a view of reducing the first cost, but of improving the fire-resisting qualities.

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Mr. Wason has made an extensive comparison of different formulas, most of which are convertible, one into the other, by changes in constants, and in the form of the stress-strain curve. The writer has no doubt that the percentages of steel worked out by himself are well within safe limits; he intended that they should be. If economy demanded it, he would not hesitate to increase them by at least 10 per cent. This, in the particular case assumed, would probably have given values more satisfactory to Mr. Wason.

However, Mr. Wason's mathematical work is not quite consistent. In his use of Professor Talbot's formulas, he assumes the value of $A$, overlooking the fact that there is a certain value of $A$ which necessarily follows from his previous assumptions, and which Professor Talbot's formulas afford the means of determining. If Mr. Wason will take the writer's Equations 1 to 5, revise them to suit the assumption of a parabolic stress-strain curve with its vertex on the extreme fiber in compression, and assume $\frac{E_c}{E_s} = \frac{1}{20}$, he will get a set of formulas which are absolutely convertible into Professor Talbot's when developed under the assumptions made by Mr. Wason. He will find, also, that, with such a stress-strain curve, a value of $\frac{1}{10}$ for $n$ in Professor Talbot's formulas is the same assumption as a value of $\frac{1}{20}$ for $\frac{E_c}{E_s}$ in the writer's formulas, revised for the parabolic curve.

Mr. Wason's own formula is based upon impossible assumptions. If the neutral axis is at the middle, the upper half—not the upper third—is in compression. Solving for working stresses, the right line is undoubtedly the correct form for the stress-strain curve. Under these circumstances, the maximum fiber stress in beams designed by Mr. Wason's formula is 667, instead of 500, lb. per sq. in. Moreover, in Mr. Wason's method, there is nothing to indicate that if he had used 100 000 instead of 50 000 for $f$, he would have obtained a different value of $A$; in which case, his formula would make the resisting moment of his beam 1 500 000, instead of 750 000 in-lb. Mr. Wason would not consider the beam good for that, but if his formula were written into a building law, some one else might. As a matter of fact, in his formulas, Mr. Wason does not take account of the elastic properties of the materials at all.

At the bottom of page 256,* Mr. Wason makes an interesting calculation, which is a good argument for using a curved form of stress-strain curve, and solving for stresses near the ultimate, since the right-line-working-stress method puts the concrete at a manifestly unfair disadvantage. In Mr. Wason's computation of the

* *Proceedings*, Am. Soc. C. E., for March, 1906.

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compressive force of concrete, under the parabolic assumption, however, the coefficient, $\frac{5}{8}$, should be $\frac{2}{3}$. The coefficient, $\frac{5}{8}$, belongs, however, to a curve much closer to the truth than a parabola, and the lever arm of 0.8125 $d$ is quite safe. There is no doubt that the beam assumed by Mr. Wason would easily carry 2 sq. in. of reinforcement, and that it would not then collapse under less than 1 000 000 in-lb., if properly designed and built.

It seems to the writer that compression in the steel, due to shrinkage of the concrete, is merely the tensile strength of the concrete in another form. It is an additional argument for attached web members.

The Watertown tests indicate that, with increasing age, the ultimate strength of the concrete increases more rapidly than the modulus of elasticity. This increases somewhat the factor of safety, but does not in any way affect the economy of the design.

The tests with loose diagonal stirrups, cited by Mr. Wason, seem to prove very conclusively the existence of the diagonal web stresses, and the necessity for rigid attachment of the web members, resisting them, to the main bars. Mr. Wason is entirely mistaken as to the difficulty of assembling and handling such reinforcement as was used at the War College. The web members were so rigid that the entire reinforcement was easily handled as a whole; the cost, in place, was about 2.4 cents per lb. The concrete was made of small gravel, and poured in, very wet. The writer does not believe that any one of the systems of web reinforcement described by Mr. Wason is as cheap or as easily handled and embedded as that used at the War College.

The equation deduced by the writer for the cost of the variable elements of a reinforced concrete beam is a hyperbola, which, when plotted, would almost coincide with the curve of total cost in Fig. 24, of Mr. Goodrich's discussion.

In answer to Mr. Goodrich's comments, on page 277,* relative to the quantities, $s$, $b$, and $c$, this really raises the question of maximum economy in the spacing of ribs. With a given system of centering, this problem is capable of solution, but it would have to be solved separately for each case. Practical considerations will generally restrict the number of bays into which a given space can be divided, but a mathematical discussion of minimum cost might be useful in each case, as indicating which of the available numbers of bays is most economical.

It seems to the writer that Mr. Goodrich's brick beams had a type of connection between web members and main bars which, when deflection had taken up the slack, became quite rigid, because of

* *Proceedings*, Am. Soc. C. E., for March, 1905.

the friction. If he had set the U's the other way, the experiment would have been more conclusive. As it was, it appears to be quite as much in favor of his contentions as against them. If the stirrups of the beams shown in Plate XXVIII were wrapped closely around the main bars, the same is true of them. Captain Sewell.

Mr. Goodrich, as well as Mr. Turner, expresses some doubt as to the correctness of the ordinary assumptions made in designing reinforced concrete structures. It will not be denied that, for isolated beams, the theory of flexure explains the results of tests fairly well. Slabs reinforced in two directions and supported on all sides may give results a little higher than would be indicated by the theory of flexure as ordinarily applied, and this may be due, in some measure, to the counterbalancing effects of compressive stresses acting at right angles to each other, on the same material. But it is not clear how the two sets of reinforcing bars could relieve each other of tensile deformation in the same way, so that an isolated slab built and supported as described, would probably not carry much more than the breaking loads found by the theory of flexure, rationally applied. Any increase in strength could be allowed for by a judicious reduction of applied moments in designing.

When a slab or beam is rigidly built in as part of an extended structure, however, there is a very great increase of strength under tests applied to only one or two units of the floor system at a time, especially when they are interior units. Exactly the same results have been attainable with steel structures, any time during the last twenty years, but no one has thought it advisable to do so, and count upon them. If not advisable for a tough and ductile material like steel, it is much less advisable for a brittle material like concrete. If dome action is to be counted upon, then build domes, self-contained, each within its own tension ring—not slabs and beams, dependent upon unloaded and undamaged neighbors for capacity to carry, as domes, loads that applied to them, as beams, would instantaneously and completely destroy them. Of continuous girder action, however, the writer would take fairly full advantage; and he is convinced that it would have been advisable to do the same thing in steel structures for these many years.

In answer to Mr. Goodrich's claim that a sufficiency of tests is available to settle disputed points, it might be suggested that the manifest differences of opinion among those conversant with the subject is pretty good proof to the contrary. Beams exactly alike in all particulars except as to the type of web reinforcement and its method of attachment to the main bars, should be tested accurately, in a testing machine, with numerous points of contact, well distributed throughout the span, to prove whether the writer's theory

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of web reinforcement is or is not correct. Practical tests are not sufficiently accurate to be conclusive and to remove the question from the domain of opinion to that of established fact.

The writer desires to express his appreciation of Mr. Goodrich's very discerning, fair, and frank discussion.

Mr. Thacher's objections to the writer's proposed multiplied loads would apply to bridges and other structures in which the dead load is the principal load. A fair average case in a building would be one in which the dead and live loads are about equal. The writer's proposition, in such a case, involves a safety factor of 2½, based on conditions at a stage materially short of collapse. It is very doubtful whether the floor systems of most steel-frame buildings have any such factor; the tile arches in common use would collapse before the stress in the steel beams reached the elastic limit—and this would fix the factor at very little more than 2.

If reinforced concrete is made a little safer than the type of structures it is trying to displace, it is sufficient. Where the dead load becomes very great, however, there should be adopted a sort of sliding scale, whereby the factor of safety, based on total loads, would never be less than 2½. For structures subject to shock and vibration, it should be increased.

The writer naturally dissents from Mr. Thacher's views as to the adequacy of the concrete for binding main and web members together. However, if there is any economy in omitting the surplus concrete, in a completely reinforced beam, there is no objection to doing so, provided adequate fire resistance is not sacrificed.

In reply to Mr. Forchhammer, attention is called to the fact that the stress-strain curve used in deducing Equations 1 to 5 is correct only on the assumption of a certain maximum stress in the concrete; to allow this stress to vary as Mr. Forchhammer does, and still use the equations with the constants deduced by the writer, is manifestly incorrect. Mr. Forchhammer, in arriving at a beam of minimum cost, goes through all the tentative calculations, which the writer tried to avoid, and deduces no rule of general application.

The writer cannot see that his use of the words, "maximum allowable percentage," is misleading when they are read with the context, wherein it is plainly stated that all percentages are determined so as to cause the beam to fail by failure of the steel.

"Theoretical economy based on relative costs," is attained when the cost of the steel and the cost of the concrete above it are equal. If this gives so great a percentage of steel that the concrete will fail before the stress in the steel reaches the elastic limit, the beam is not able to resist the moment used in determining the area of the steel. A deeper or wider beam of greater cost is demanded. There-

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fore, the beam of least cost, determined solely by consideration of the relative cost of the two materials is not adequate, from a structural point of view, and cannot be used. The maximum attainable economy, of course, results from using the "maximum allowable percentage" of steel. When more than this is used, the strength of the beam is increased, but not in proportion to the increased area of steel nor to the increased cost. It may not be quite accurate to say that the increase in the steel is all "wasted," but it is certainly not economically used. There may be cases where dead weight must be avoided at any cost—or where minimum thicknesses must prevail—in which the design must be based on the use of very large percentages of steel; but ordinarily this is not necessary. Where the strength of the concrete determines the failure of the beam or slab, the failure is apt to be sudden, and to come without much warning. This is a very undesirable kind of failure, and should be avoided, if possible. As already pointed out, if concrete is so expensive that it is cheaper to design on the basis of the strength of the concrete, it is probably still cheaper to use structural steel and some form of fire-proof floor arch, such as hollow tiles.

In reply to Mr. French, there is no objection to designing by the straight-line formulas, for working stresses, provided values are assumed for $\frac{E_c}{E_s}$ and $F$, which will be as near the truth as possible, and at the same time, will permit of the use of reinforced concrete with a safety factor only a little greater than that existing in structural steelwork designed to carry the same loads. Building departments will not ordinarily approve designs frankly made with such values of $\frac{E_c}{E_s}$ and $F$—especially the latter—yet they will pass lighter designs made in accordance with a purely empirical formula in which a fictitious working stress of 500 lb. or less is one of the factors, and an utterly impossible value for the area of compression is another. The writer frankly admits that his chief reason for recommending the method of multiplied loads and ultimate stresses is the hope that it may the more easily lead to designing by honest formulas, with reasonable factors of safety. The writer often designs for working stresses, but, fortunately, does not have to reckon with any building department.

The writer is much indebted to Professor Church for working out the more general solution of his problem in maxima and minima, thereby avoiding the slight inaccuracy of assuming a fixed value for the coefficient, $h$. That the writer himself evaded this issue should, at least, relieve him of the suspicion of being a mathematical gymnast, which seems to have been aroused in the minds of some by the very modest mathematical exercises contained

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in the paper. It should be pointed out, however, that the more rigid method followed by Professor Church, when applied to the practical case in which there is a minimum, states the conditions of minimum cost in terms of relative stresses in the steel and concrete. To determine the actual area of steel in the design of minimum cost would then involve the solution of Equations 1 to 5. The writer's method does not give, with rigid accuracy, the theoretical minimum; but it comes close enough for all practical purposes, and gives the result in more convenient form for use.

The question of combined thrust and moment raised by Mr. Leffler is one of extreme interest. This was not discussed in the paper because the writer does not believe in relying upon arch action in floor systems as ordinarily designed. Therefore, he confined himself to a consideration of stresses due to bending only. The simplified formula recommended by the writer is just as applicable to working stresses as to ultimate stresses, but, as it is concerned with the steel alone, it would not serve for the combined thrust and moment problem, without the use of special values of $\frac{a}{d}$.

Replying to Mr. Hill, the writer would not recommend the duplication of his own mathematical work in any case; the general rule that minimum cost will result when the cost of the steel is as nearly as possible equal to that of the concrete above it, is the only practical result of the application of the calculus, and it is merely one point that should be kept in mind, along with the cost of centering, variations in the prices of steel and cement, caprices of the labor unions, etc.

In reference to the dehydration of cement, mentioned by Mr. Hill, if attached web members are not used, concrete which is at all dehydrated would certainly not be reliable for transmitting stresses into the steel. Even if attached web members are used, the concrete surrounding the main bars will take some stress; although this action is not counted upon, it cannot be entirely avoided. Dehydrated concrete would be very apt to crack and fall off, under such circumstances; in any case, unless it is removed and good material substituted, the damage is not wholly repaired, and the structure is not as good a fire risk as it was before.

The last paragraph of Mr. Hill's discussion is of the utmost importance, and should receive most careful consideration.

Mr. Shearwood also raises some extremely important points, which should be settled by careful experimental investigation. The point about the effect of repeated loads is one of great interest; personally, the writer believes that experiments along this line will demonstrate the value of attached web members, but frankly admits that, thus far, this is only an opinion.

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| CHARLES S. GOWEN, | J. WALDO SMITH, | AUSTIN L. BOWMAN, |
| GEORGE GIBBS, | ONWARD BATES, | RALPH MODJESKI, |
| M. L. HOLMAN, | BERNARD R. GREEN, | HEZEKIAH BISSELL, |
| GEORGE S. PIERSON. | GEORGE S. WEBSTER. | CHARLES WARREN HUNT. |

## Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON RAIL SECTIONS:—Joseph T. Richards, C. W. Buchholz, E. C. Carter, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

ON CONCRETE AND REINFORCED CONCRETE:—C. C. Schneider, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, J. W. Schaub, Emil Swensson, A. N. Talbot, J. R. Worcester.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER: - - - 533 Columbus.
CABLE ADDRESS: "Ceas, New York."

Vol. XXXII. AUGUST, 1906. No. 6.

# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## SOCIETY AFFAIRS.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

**June 6th, 1906.**—The meeting was called to order at 8.35 P. M.; President Frederic P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, 107 members and 19 guests.

The minutes of the meetings of May 2d and 16th, 1906, were approved as printed in the *Proceedings* for May, 1906.

A paper by H. deB. Parsons, M. Am. Soc. C. E., entitled "Disposal of Municipal Refuse, and Rubbish Incineration," was presented by the author and illustrated with lantern slides. The subject was discussed by George A. Soper, M. Am. Soc. C. E.

179686

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Henry Sewall Adams, Boston, Mass.
Axel Samuel Frederick Berquist, New York City.
Walter John Cahill, Chicago, Ill.
Frederick Giddings, Atchison, Kans.
Frederick Taylor Hepburn, Altoona, Pa.
Harry Nelson Latey, New York City.
Frederick William Lovell, Cleveland, Ohio.
George Alexander Orrok, Flatbush, N. Y.
Orlando Kenton Parker, Los Angeles, Cal.
Charles Ezra Perkins, Columbus, Ohio.
Edward Austin Tucker, Boston, Mass.
Albert Wolstenholme, Fall River, Mass.

As Associate Members.

Charles Johnstone Armstrong, Johannesburg, South Africa.
Arthur Raymond Baylis, Flatbush, N. Y.
George Safford Beal, Rome, N. Y.
Paul Chapman, New York City.
Howard Michael Cryder, St. Louis, Mo.
Charles Leonard DeMott, Lynchburg, Va.
Joseph Goodman, New York City.
John Walter Heller, Brooklyn, N. Y.
John Mifflin Hood, Jr., Baltimore, Md.
Ransome Tedrowe Lewis, Elmira, N. Y.
George Riddick Mackenzie, Philadelphia, Pa.
Elijah Hunter Owen, Chagrin Falls, Ohio.
James Rowland Potter, Downington, Pa.
Hugh Percival Raikes, Birmingham, England.
Oliver Thomas Reedy, Livingstone, Ariz.
Francis Murphy Sawyer, Newport, Pa.
Alfred Yngve Sundstrom, Steelton, Pa.
Andrew Swickard, San Francisco, Cal.
Charles Winthrop Tarr, Cape May, N. J.
Howard Flanders Taylor, Kansas City, Mo.
Robert William Taylor, Jr., Brownsville, Pa.
Alfred Howe Terry, New Haven, Conn.
Victor Roy Walling, Cananea, Sonora, Mexico.
Arthur Ellsworth Winslow, Northfield, Vt.
Nathaniel Alston Yuille, Demopolis, Ala.

As Associate.

Harrison Washburn Hayward, Boston, Mass.

The Secretary announced:

The transfer of the following candidates by the Board of Direction, on June 5th, 1906:

From Associate Member to Member.

Louis Jacob Affelder, Pittsburg, Pa.
Benjamin Franklin, Philadelphia, Pa.
Richard Henwood Gillespie, New York City.
John Philip Hallihan, El Paso, Tex.
Léon Élie Lion, Monroe, La.
William Augustus Moncure, Philadelphia, Pa.
Joseph Christian Wagner, Philadelphia, Pa.

The election of the following candidates, by the Board of Direction:

As Juniors.

On February 6th, 1906:

Walter Harris Ratcliff, Berkeley, Cal.

On May 1st, 1906:

Ralph Melvin Connor, Minidoka, Idaho.

On June 5th, 1906:

Clarence Arminger Bingham, Elizabeth, N. J.
Orville Green Bennet, Jr., New York City.
James Powell Murray, Iloilo, Philippine Islands.
Augustus Taber Parsons, Quincy, Cal.
William Henry Snyder, Albany, N. Y.

The Secretary announced the following deaths:

Robert Bennett Gorsuch, Secretary and Treasurer, November 5th, 1852, to November 2d, 1853; elected Honorary Member, January 9th, 1905; died June 2d, 1906.

David Ashley Poynor, elected Member, June 1st, 1892; died May 29th, 1906.

Adjourned.

## THIRTY-EIGHTH ANNUAL CONVENTION, HELD AT "THE FRONTENAC," FRONTENAC, THOUSAND ISLANDS, N. Y., JUNE 26th, 27th, 28th and 29th, 1906.

### BUSINESS MEETING.

**(First Session of the Convention), Tuesday, June 26th, 1906.**— The meeting was called to order at 10 A. M.; President F. P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, about 125 members.

The report of the Secretary on the result of the ballots on Time and Place for holding the Annual Convention of 1907, was presented.

On motion, duly seconded, the matter was referred to the Board of Direction, with power.

The report of the Special Committee on Rail Sections, which was presented at the Annual Meeting, January 17th, 1906, and made on order of business for discussion at this meeting, was presented.

The following motion was adopted:

"That the Report of the Special Committee on Rail Sections be referred back to the Committee for further action and final report, in the hope that the majority and minority may harmonize their views and present a unanimous report."

The report of the Committee on Amendments to the Constitution was presented by M. R. Sherrerd, M. Am. Soc. C. E. A Minority Report was presented by John C. Trautwine, Jr., Assoc. Am. Soc. C. E., and, after discussion, it was moved, seconded and carried, that the report of the Committee be printed and brought up for further discussion at an adjourned meeting.

The Secretary presented the following resolution, which had been referred to the Board of Direction, together with a recommendation from the Board that it be sent out for letter-ballot.

"*Resolved,* That a Special Committee be appointed to collect such information as may be obtainable on the present and prospective status of the adoption of the metric system in the United States, and to collate and systematize such information and promulgate it to the Society in form of reports from time to time."

On motion, duly seconded, the recommendation of the Board was adopted.

The Secretary presented a report in reference to the Society House and the real estate assets of the Society.

The Secretary presented a report in reference to a bronze tablet erected by the Society in Washington University, St. Louis, to commemorate the International Engineering Congress held at St. Louis in 1904.

The Secretary presented a communication from Charles Macdonald, M. Am. Soc. C. E., and Mrs. Macdonald, inviting all in attendance at the Convention to take luncheon with them at Gananoque on Wednesday, June 27th, 1906.

Adjourned, subject to the call of the President.

## ADJOURNED BUSINESS MEETING.

**(Fourth Session of the Convention), Wednesday, June 27th, 1906.**—The meeting was called to order at 8.30 P. M.; President F. P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, about 90 members.

The following resolution was adopted:

*"Resolved,* That it is the sense of this meeting that a Special Committee be appointed to report on the status of Engineering Education in this country, and to recommend measures calculated to place it on the highest plane of efficiency."

On motion the above resolution was referred to the Board of Direction, under the provisions of Article VI, Section 12, of the Constitution.

The proposed amendments to the Constitution were then considered, and, after discussion, the following was adopted:

"That the proposed amendments be referred back to the Committee for further consideration and report, with instructions to place such report in the hands of the Secretary at least sixty days prior to the Annual Meeting so that copies of it may be sent to the membership in advance of that meeting."

The Secretary presented a letter and resolution from J. G. Spielman, Assoc. M. Am. Soc. C. E., proposing the appointment of a Special Committee on Building Ordinances and Regulations in the larger cities.

Adjourned.

**Second Session, Tuesday, June 26th, 1906.**—The meeting was called to order at 8.30 P. M.; President F. P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, about 250 persons.

The President delivered the Annual Address: "The Development of Water Supplies and Water-Supply Engineering."

Adjourned.

**Third Session, Wednesday, June 27th, 1906.**—The meeting was called to order at 9.30 A. M.; President F. P. Stearns in the chair;

Chas. Warren Hunt, Secretary; and present, also, about 100 members and guests.

Discussion on the following subjects was called for by the President:

"What is the Best Preparatory Education for the Civil Engineering Profession?"

"Is Technical Training the Best Education for Executive Work?"

The discussion was opened by a communication from GEORGE F. SWAIN, M. AM. SOC. C. E., which was read by the Secretary, and the discussion was continued by the following:

BERNARD R. GREEN, M. AM. SOC. C. E.
EDGAR MARBURG, M. AM. SOC. C. E.
GARDNER S. WILLIAMS, M. AM. SOC. C. E.
OLIN H. LANDRETH, M. AM. SOC. C. E.
EDWIN F. WENDT, M. AM. SOC. C. E.
A. N. TALBOT, M. AM. SOC. C. E.
F. R. COATES, ASSOC. M. AM. SOC. C. E.

The Secretary announced that he had received communications on these topics from Messrs. Harold Bouton and George W. Rafter, which could not be presented for lack of time, but would be printed with the other discussions in *Proceedings*.

The President called for discussion on the following topic:

"The Protection of the Intellectual Property of Civil Engineers."

The Secretary presented a written discussion, by D. A. USINA, ASSOC. AM. SOC. C. E., and the topic was discussed further by J. P. A. MAIGNEN, ASSOC. AM. SOC. C. E.

Adjourned.

**Fifth Session, Thursday, June 28th, 1906.**—The meeting was called to order at 8.30 P. M.; President F. P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, about 100 members and a number of guests.

The Secretary presented a letter from J. Sterling Deans, inviting the members present at the Convention to visit and inspect the St. Lawrence River Bridge near Quebec. The condition of the work on the bridge was described by O. J. West, Assoc. M. Am. Soc. C. E., who also detailed the arrangements made for the reception and care of visitors.

The President called for discussion on the following topic:

"The Advance in Sewage Disposal."

GEORGE C. WHIPPLE, ASSOC. M. AM. SOC. C. E., opened the discussion, and the following members presented their views:

EMIL KUICHLING, M. AM. SOC. C. E.
JOHN W. ALVORD, M. AM. SOC. C. E.
W. S. JOHNSON, ASSOC. M. AM. SOC. C. E.
J. P. A. MAIGNEN, ASSOC. AM. SOC. C. E.
J. H. GREGORY, ASSOC. M. AM. SOC. C. E.
JAMES OWEN, M. AM. SOC. C. E.

The Secretary announced that he had received written communications on this topic from Messrs. George W. Rafter and R. Winthrop Pratt, which would be printed in *Proceedings*.

The following resolution was unanimously adopted:

"*Resolved*, That the members of the American Society of Civil Engineers, in session at Frontenac, send greetings to Mr. Charles Macdonald and his family, and tender to them a hearty vote of thanks for the cordial reception and very charming entertainment extended to the members and guests in attendance at the Convention."

The President called for discussion on the following topic:

"What are the Best Means for the Prevention of Conflagrations in Large Cities?"

The discussion was opened by JOHN R. FREEMAN, M. AM. SOC. C. E., and was continued by RUDOLPH P. MILLER, M. AM. SOC. C. E.

It was moved, seconded and carried that discussion on the topic, "The Filtration of Water," be confined to correspondence.

Adjourned.

## ELECTIONS TO MEMBERSHIP.

The following candidates were elected on ballot canvassed July 9th, 1906:

AS MEMBERS.

FREDERICK ADAMS, Salina Cruz, Oaxaca, Mexico.
J GEORGE BLOOM, Topeka, Kans.
WATSON GEROULD CLARK, Tenafly, N. J.
NOAH WILSON DAVIS, Charlestown, W. Va.
MANUEL VICTOR DOMENECH, Ponce, Porto Rico.
WILLIAM ROBERT DUNHAM, JR., Providence, R. I.
HOWARD AUGUSTUS FITCH, Minneapolis, Minn.
ROBERT BOTELER KENRICK, Montreal, Que., Canada.
WILSON SHERMAN KINNEAR, Detroit, Mich.

CHARLES WILLIAM KNIGHT, Rome, N. Y.
WILLIAM RIDLEY NEELY, West Point, N. Y.
MARIUS NYEBOE, Copenhagen, Denmark.
ANGEL PEIMBERT, Mexico City, Mexico.
PAUL LYON REED, Olongapo, Philippine Islands.
OSCAR SHANKS, Pittsburg, Pa.
ROBERT COLFAX SMITH, Chicago, Ill.

AS ASSOCIATE MEMBERS.

JOHN CASPAR AVAKIAN, Los Angeles, Cal.
WILLIAM JAMES BACKES, Hartford, Conn.
FRANK GEORGE BAUM, San Francisco, Cal.
DAVID ELDER BAXTER, New York City.
EDWIN PACKARD BLISS, Boston, Mass.
MILES ELIJAH BROOKS, Barnesdale, Ont., Canada.
REDMOND STEPHEN COLNON, St. Louis, Mo.
FREDERICK HOSMER COOKE, Cavite, Philippine Islands.
THOMAS WHITE COTHRAN, Warm Springs, Ga.
LEONARD SMITH DOTEN, Washington, D. C.
ROBERT FARNHAM, JR., Washington, D. C.
SQUIRE EARNEST FITCH, Galeton, Pa.
MANSFIELD JOSEPH FRENCH, Utica, N. Y.
WALTER JOSEPH GRAVES, Detroit, Mich.
HARRY LEWIS HAEHL, San Francisco, Cal.
GERARDO IMMEDIATO, Necaxa, Puebla, Mexico.
EDWARD ALLEN KEYS, Keshena, Wis.
FRANK PERRY LARMON, Waterford, N. Y.
ARTHUR HERMANN MARKWART, Berkeley, Cal.
NEAL ALBERT MELICK, Norfolk, Va.
MORTIMER ADAM MUNN, Baltimore, Md.
WILLIAM AUGUSTINE NIAL, New York City.
PAUL HOWES NORCROSS, New York City.
ALBERT ALLEN NORTHOP, West Shokan, N. Y.
RICHARD SCHERMERHORN, JR., New York City.
EDGAR ERNEST SEYFERT, Philadelphia, Pa.
CURLYS LYON SLOCUM, New Haven, Conn.
CHARLES HERMAN SNYDER, Oswego, N. Y.
LOUIS RICHARD STOCKMAN, Babb, Mont.
COLUMBUS WILLIAM THORN, Camden, N. J.
JOHN WARE, Connellsville, Pa.
LEVI ROMULUS WHITTED, Anniston, Ala.
FREDERICK WHITEFIELD WITHERELL, Harrisburg, Pa.
ALLAN SHELDON WOODLE, JR., Wheeling, W. Va.

As Associates.

John Griffiths Brown, Philadelphia, Pa.
George La Pierre Denio, Ridgewood, N. J.
John Baptiste Lober, Philadelphia, Pa.
Edward John Schneider, Kansas City, Mo.

## OF THE BOARD OF DIRECTION.

(Abstract.)

**June 5th, 1906.**—President Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bates, Bissell, Bowman, Ellis, Gibbs, Gowen, Knap, Kuichling, Schneider, Smith, and Swensson.

A report from the Building Committee was presented stating that the final estimate of the Architects in favor of William L. Crow, Builder, amounting to $57 420.83, and in favor of Mitchell-Vance Co., for lighting fixtures, amounting to $996.60, had been approved; that, with the addition of the Architects' commission, amounting to $2 920.87, the total cost of the addition to the building had been $61 338.30. The report was accepted, and the Committee requested to prepare a general report on the subject of the addition to the Society House for the information of the Society.

The following resolution referred to the Board by the Society at the meeting May 2d, 1906, was considered:

"*Resolved,* That a Special Committee be appointed to collect such information as may be obtainable on the present and prospective status of the adoption of the Metric System in the United States, and to collect and systematize such information and promulgate it to the Society in form of reports from time to time."

It was resolved that the Board recommend to the Society the appointment of the Special Committee for the purpose stated, and that the following be given as the reasons for and against the appointment of such committee:

1. The argument in favor of the appointment of such Committee being that some information may be transmitted through such Committee to the Society, and that no harm can be done by the appointment of such a Committee.

2. There does not seem to be any argument against the appointment of such a Committee.

E. B. Van Winkle, Rudolph Hering and Chas. Warren Hunt were appointed a Committee to prepare a memoir of the late J. James R. Croes, Past-President, Am. Soc. C. E.

The Secretary reported that in accordance with the authority of a meeting of the Society, he had purchased and forwarded to the Secretary of the Technical Society of the Pacific Coast, in San Francisco, office instruments and supplies to the amount of about $500, for distribution to Engineers in need of such tools, and that this donation by the Society had been of considerable service.

Applications were considered, and other routine business transacted.

Seven Associate Members were transferred to the grade of Member, and five candidates for Junior were elected.*

Adjourned.

* See page 195.

## REPORT IN FULL OF THE BUSINESS MEETING HELD DURING THE THIRTY-EIGHTH ANNUAL CONVENTION AT "THE FRONTENAC," FRONTENAC, NEW YORK.

**Tuesday, June 26th, 1906.—First Session.—10 o'clock A. M.**—President F. P. Stearns in the chair; Charles Warren Hunt, Secretary; and present, also, about 125 members.

Business Meeting Called to Order.

THE PRESIDENT.—The meeting will please come to order. The Thirty-Eighth Annual Convention is now open. This is the Business Meeting. The first matter to be taken up is the time and place for holding the next Annual Convention.

The Secretary presented the following report:

### REPORT OF THE SECRETARY IN RELATION TO THE VOTES RECEIVED ON TIME AND PLACE FOR HOLDING THE ANNUAL CONVENTION OF 1907.

Convention of 1907.

"Total number of votes received, 314.

"As to the place for holding the Convention, as follows:

"14 votes have been received for Colorado Springs, and

"12 votes for Denver, Colo. In addition to this,

"24 votes have been received for Denver or Colorado Springs.

"It would appear, therefore, that from 36 to 38 members of the Society are in favor of holding the Convention at one of these two places.

"32 votes have been received for Duluth, Minn.

"20 votes have been received for Boston, Mass.

"14 votes have been received for San Francisco, Cal.

"13 votes have been received for Atlantic City, N. J.

"The following have 10 votes each:

Chicago, Ill.
Norfolk, Va.
Old Point Comfort, Va.

"The following have 9 votes each:

New York City.
Washington, D. C.

"The following have 6 votes each:

Jamestown, Va.
Niagara Falls, N. Y.
Pittsburg, Pa.

"The following have 5 votes each:

Baltimore, Md.
Havana, Cuba.
New Orleans, La.
Seattle, Wash.

"The following have 4 votes each:

Chattanooga, Tenn.
Detroit, Mich.
Los Angeles, Cal.
Mackinac Island.
Minneapolis, Minn.
Quebec, Canada.
St. Paul, Minn.

Convention of 1907 (Continued).

"The following have 3 votes each:

Cape May, N. J.
Mexico City.
Montreal, Canada.
Richmond, Va.
Salt Lake City, Utah.
St. Louis, Mo.
Saratoga, N. Y.

"The following have 2 votes each:

Birmingham, Ala.
Buffalo, N. Y.
Columbus, Ohio.
Louisville, Ky.
Newport, R. I.
Philadelphia, Pa.
Portland, Me.
On Steamer, Buffalo-Duluth.

"The following have 1 vote each:

Panama.
San Antonio, Texas.
Kansas City, Mo.
Yellowstone Park.
Savannah, Ga.
Toledo, Ohio.
Toronto, Ont.
Mammoth Cave, Ky.
Ellenville, N. Y.
Bar Harbor, Me.
Portsmouth, N. H.
Watch Hill, R. I.
Providence, R. I.
Rangeley Lakes, Me.
Albany, N. Y.
Lake George, N. Y.
White Mountains.
Halifax, Nova Scotia.
Thousand Islands.
Palm Beach, Fla.
London, England.
Glasgow, Scotland.
Oriental Hotel, Manhattan Beach, N. Y.
Any City on the Great Lakes.
Some resort on Lakes Erie or Michigan.
Some place in the South or West.
San Francisco or neighboring City.
Some place in California.
Vicinity of Kansas City.
Some western point.
Maine Coast.
Some southern City.

Summer resort having large enough hotel (one) to hold all attending members.

Some western point convenient to one of the large Reclamation Service Projects.

"As to the time for holding the Convention, the following votes have been received:

| | | | |
|---|---|---|---|
| February | 1 | Jamestown Exposition | 3 |
| March | 1 | May or June | 2 |
| April | 3 | July or August | 2 |
| May | 23 | December or January | 1 |
| June | 148 | Autumn | 1 |
| July | 51 | Earlier than usual, a month if possible | 1 |
| August | 4 | | |
| September | 11 | Between December and April | 1 |
| October | 8 | October to June | 1 |
| November | 1 | A seasonable time | 1 |
| June or July | 13 | Some winter month | 1 |

"Respectfully submitted,

"CHAS. WARREN HUNT,
*"Secretary."*

"NEW YORK, June 20th, 1906."

THE SECRETARY.—There have been a number of letters received advocating holding the next Convention in different places. I have one which I think should be read. Letter from Ellis B. Noyes.

"200 DINWIDDIE ST.,
"PORTSMOUTH, VA., June 21, 1906.

"MR. CHARLES WARREN HUNT,
*"Secretary, American Society of Civil Engineers,*
"New York, N. Y.

"DEAR SIR:—Since the landing of the first permanent English settlers in this country on Jamestown Island is to be celebrated by an Exposition and Naval Rendezvous at the City of Norfolk, Va., during the year 1907, I, in behalf of the "Associated Engineers and Constructors Society of Tidewater Virginia" hereby invite the American Society of Civil Engineers to hold their Annual Convention for the year 1907 at the Jamestown Ter-centennial Exposition at the City of Norfolk, Va.

Respectfully,
"ELLIS B. NOYES, M. AM. SOC. C. E.
*"President of the Associated Engineers and Constructors Society of Tidewater Virginia."*

I might add that an agent of the Exposition has been following me around for the last four or five days. I also have an invitation from Niagara Falls, from the Bureau of Publicity, which I do not think it is necessary to read, also a communication signed by the Mayor of Niagara Falls. There is another invitation from the Jamestown Exposition, signed by the Chief of the Department of Congresses and Special Events.

I also have a letter from the Citizens' Business Association of Newport, R. I.

"NEWPORT, R. I., June 23, 1906. Letter from Benj. G. Oman.

"MR. CHAS. WARREN HUNT, *Secretary,*
*"American Society Civil Engineers,*
"c/o Hotel Frontenac,
"Thousand Islands, Canada.

"DEAR SIR:—At a meeting of the Executive Committee of the Citizens Business Association of Newport, R. I., held on Friday evening, June 22, it was unanimously voted:—

" 'That a most cordial invitation be forwarded to the American Society of Civil Engineers, urging them to make Newport the headquarters for their convention for the year 1907, assuring this Society that Newport and its Citizens will consider such a decision an honor to the city and its people, and that every effort will be made to make their stay a pleasant and profitable one.'

"The Association wishes to make the fact thoroughly understood, that anything the Society may ask them to do in aiding them to arrange details for the Convention will be gladly done. At the same time we have a hall, modern in all its appointments, with ante-rooms

Convention of 1907 (Continued).

adjoining, which will be freely placed at the disposal of the Society. Hotel accommodations will be secured, in fact any details that may be requested by the Society.

"'Come to Newport, Rhode Island, in 1907.'

"You will receive under separate cover, a booklet on Newport.

"Very truly yours,

"BENJAMIN G. OMAN,

*"Secretary, Citizens Business Association."*

I believe, Mr. President, that that is all I have on that subject.

THE PRESIDENT.—You have heard the various opinions of members of our Society in regard to the time and place for holding the next Annual Convention. As is usually the case where there is no concerted action, there is no unanimity of opinion. What is the pleasure of the meeting?

J. A. OCKERSON, M. AM. SOC. C. E.—In view of the number of votes cast for Duluth at this time, I should be glad if there would be some explanation of the outcry last season. I have heard that there was not sufficient accommodation for the Society at that point. I should be glad to hear whether the officers of the Society have investigated that matter.

THE SECRETARY.—There was a resolution passed at the last Annual Convention which, in effect, confined the choice of the Board of Direction for this Convention, and I am pretty sure it confined it for all future Conventions, to a hotel that would accommodate the whole Convention, and that fact was largely responsible in the selection of this place, and in not choosing Duluth.

GARDNER S. WILLIAMS, M. AM. SOC. C. E.—I would like to inquire if that motion did bind the action of the Board of Direction for all future time. I am under the impression that it did for this year.

THE SECRETARY.—The Secretary has to acknowledge that he was wrong, for, on reading the resolution, he finds a statement by the then President of the Society, that this resolution does not bind the Board of Direction in any way.

G. E. THACKRAY, M. AM. SOC. C. E.—Was not that a simple suggestion?

THE SECRETARY.—The resolution is as follows:

*"Resolved,* That the sense of this meeting is that the 1906 Annual Convention of the American Society of Civil Engineers be held at a summer resort having a hotel large enough to accommodate the entire attending membership, and that the time of holding said convention shall be the latter part of May if the place is in the southern half of the United States, and in the first part of June if the place is in the northern half, and

*"It is Further Resolved,* That the selection of the place of meeting be referred to the Board of Direction with power to act under the above resolution."

That was somewhat amended, although as to the time only, not confining the Board of Direction to the time specified.

THE PRESIDENT.—The motion before the Convention is that the time and place of holding the next Annual Convention be left to the Board of Direction. Is that the motion?

(Motion seconded.)

MR. WILLIAMS.—I wish to say a word in regard to the general proposition of places of holding the Convention. I think it will be found that the membership of this Society is divided into two classes, one of which favors the selection of such a place as this, and they are the ones who are here to-day. There is, however, a very large membership who do not feel able to come to places of this sort, or do not feel sufficiently repaid by trips of this sort; that is, the social feature of the Society, which is a prominent one in a case of this kind, does not appeal to them so strongly, because they have not the wide range of acquaintanceship that some others have, and therefore prefer to attend conventions in places where there is something besides the convention to attract; and it seems to me that their views should be given weight at times in the selection of places.

Now, I have heard certain members say that another such convention as the one at Asheville would be fatal to the Society. That, I consider an extreme view. I was not on the Asheville trip. It has been a regret with me that I was not. I would have been there had circumstances permitted. I do not belong to that class at all, but at the same time I recognize their right to be heard in this matter, and, as I think very few, if any, of them are present at this meeting, I wish to call attention to their view of the matter when it is being considered by the Board of Direction.

I do not intend to introduce any amendment or any resolution, but simply wish to call attention to the fact that such a sentiment is existent among a considerable number of the younger and less prominent members of the Society, and that I think the future welfare of the Society demands that some consideration be given to their views in this matter; that we shall not confine ourselves exclusively to conventions at such points as this, although I venture to say that those who are here this morning would prefer to come to a place like this for our conventions.

THE PRESIDENT.—Any further remarks on this subject? You have heard the motion. Those in favor will say "aye"; those opposed, "no."

The motion is carried unanimously.

Report of Special Committee on Rail Sections.

THE PRESIDENT.—The next matter is the Report of the Special Committee on Rail Sections, brought up for discussion at this meeting by order of the Board of Direction. There are some reports

Report of Special Committee on Rail Sections (Continued).

which will be distributed. While these reports are being distributed the Secretary will read a telegram which he has received relating to this subject.

THE SECRETARY.—It is from Mr. Robert W. Hunt, the Secretary of this Committee:

"Imperative business, occurring even after starting to depot, prevents attendance. Greatly regret but uncontrollable. Desire to discuss Rail Committee's report advocating its adoption as presented by majority. Can only ask you, if advisable, to announce my strong advocacy of that action. Please answer.

"ROBERT W. HUNT."

THE PRESIDENT.—This report is that of the Special Committee on Rail Sections, made at the Annual Meeting of the Society, and is signed by eight members. There are four minority reports, one signed by John D. Isaacs, one by William R. Webster, one by Percival Roberts, Jr., and one by George E. Thackray. The report is now ready for discussion.

MR. THACKRAY.—In the absence of many, or any, of the other members of that Rail Committee, I do not feel that it would be either wise, expedient, or courteous for me and the minority members to say very much, and, as the majority is not here, I would respectfully suggest that the matter be referred back to the Committee in the hope that they may harmonize their views, and present a unanimous report to the Society. Further than that, I think it is unnecessary for me to say. I therefore make the motion.

(Motion seconded.)

THE PRESIDENT.—Will you put it as a formal motion?

MR. THACKRAY.—I move that the Report of the Special Committee on Rail Sections be referred back to the Committee for further action and final report, in the hope that the majority and minority may harmonize their views and present a unanimous report.

THE PRESIDENT.—You have heard the motion, which has been seconded. Is there any further discussion? Those in favor of the motion will please say "aye"; those opposed, "no."

(Motion carried unanimously.)

EDGAR MARBURG, M. AM. SOC. C. E.—As a member of a committee of another society, namely the American Society for Testing Materials, I wish to say a word about the action a few days ago by that committee, if it is in order?

THE PRESIDENT.—By unanimous consent, you may go on.

MR. MARBURG.—I want to say that the report of this Committee served as a basis for the work of the Committee of the American Society for Testing Materials during the past year, and that com-

mittee also presented a valuable report at their Annual Meeting, which report was acted upon, as this was, in the hope that they might meet in agreement at the close of the year. The American Railway Engineering and Maintenance of Way Association, I believe, has taken action; they are taking the specifications which have been proposed by these three societies, and it is very much to be hoped that a year hence there will be something close to unanimity in those specifications.

Report of Committee on Proposed Amendments to the Constitution.

THE PRESIDENT.—The next matter to be taken up is the proposed amendment to the Constitution. We have a telegram from the Chairman of the Committee which the Secretary will read.

THE SECRETARY.—I have received from Mr. Whinery, the Chairman of this Committee, the following telegram:

"Will not be Convention. Committee report amendments goes mail to-day quick delivery."

Mr. President, this amendment was originally brought up in the proper form at the Annual Meeting, January 17th, 1906, the proposal then being as follows:

"Amend Article II, Section 2, as follows: insert after the word 'Civil' in the first line 'Engineer who shall have reached a position of recognized standing in the profession, in its several branches including.' Also strike out all of the second line beginning with the word 'Electrical' and insert 'and Electrical Engineering or in Architecture or Marine Architecture.' Also strike out all after the word 'age' in the fourth line.

"The section will then read:

"2. A Member shall be a Civil Engineer who shall have reached a position of recognized standing in the profession, in its several branches, including Military, Naval, Mining, Mechanical and Electrical Engineering or in Architecture or Marine Architecture. He shall be at the time of admission to membership not less than thirty years of age."

After the matter was discussed, it was moved, seconded and carried that the amendment be referred to a committee of five Corporate Members, one Associate and one Junior, which committee was directed to report at the next Annual Convention what, if any, changes they deemed should be made in the qualifications for each grade of membership, and submit any amendments to those amendments which they recommend. I might say further that, upon the report of the Committee, the Constitution (Art. IX, Sec. 3 and 4) states: that the amendments shall be voted upon by letter-ballot in the form as amended at said business meeting. If not so amended they shall be voted upon by letter-ballot as submitted.

THE PRESIDENT.—While we have not here the signed copy of the amendment, which is still in the mail, we have the copy in the

Report of Committee on Proposed Amendments to the Constitution (Continued).

hands of Mr. Sherrerd. I would ask Mr. Sherrerd if he would present that copy of the report of the Committee to the meeting.

M. R. SHERRERD, M. AM. SOC. C. E.—At a meeting of the Committee, held about a month or three weeks ago, at which I think all but two of the members of the Committee were present, it was practically agreed that what I shall now present would be the report of the Committee. It was to be sent around to all the members for their signatures, and was to have been here to-day. I understand that Mr. Trautwine also has some suggested changes which will be submitted by him in the shape of a minority report, and, with your permission, I will present this as the report of the majority of the Committee, asking you to take my word for the statement that the majority of the Committee have agreed to this form of suggested amendments. They are practically the amendments as submitted last year except that it has been put in what the Committee considers a better shape, with also some few changes. The principal change in the membership is to raise the age limit to thirty-three, and also to require that a man shall have reached a position of honorable high standing in the profession.

The Secretary then read the following report:

## REPORT OF THE COMMITTEE ON AMENDMENTS TO THE CONSTITUTION.

"The committee appointed at the last annual meeting of the Society (January, 1906) to which was referred certain amendments to the Constitution of the Society, presented at that meeting, now submits the following Report.

"Under the terms of its appointment the Committee was directed to 'Report to the next annual convention what, if any, changes they deem desirable in the present classification of the membership of the Society, or in the qualification for each grade of membership; and submit any amendments to these amendments which they may recommend.'

"These instructions seem to cover broadly the whole question of membership in the Society, embracing the classification of that membership, the designation of the several grades into which it is divided, and the qualification required for admission to each grade; and the Committee has taken up the subject upon this broad interpretation.

"The Committee believes that the present general classification of the active membership into Honorary Members, Members, Associate Members, Associates and Juniors, is quite satisfactory. Each of these classes or grades seems to have an appropriate and distinctive place in the organization and work of the Society. No one of them could be well dispensed with, while on the other hand, it does not appear that anything would be gained by further subdivision, or the adding of new grades.

"The grade of Fellow does not seem now to have an appropriate place in the Society, and the Committee recommends that it be discontinued, or rather allowed to expire, without prejudice to the rights and privileges of those now holding membership in that grade. If further admissions to the grade be thus discontinued it will become extinct with the death of its present members. Fellows are admitted to the Society upon the sole consideration of contribution to its permanent funds, irrespective of professional qualifications. In the earlier history of the Society these additions to our resources were needed and appreciated, and the Society will remember with gratitude the kindness of the friends who thus came to its assistance as Fellows. This grade being composed almost entirely of non-professional men (only one member of the grade being now a member in any other grade), probably confers little, if any, benefit upon its members, and does not add to the professional character of the Society.

"The question of changing the names of some or all of the present grades of membership has been carefully considered by the Committee. It is recognized that in some respects the present nomenclature is not entirely satisfactory; but, upon the whole, the Committee does not see how it can be materially improved, and recommends that no changes be made.

"It has been suggested that the name Student is preferable to Junior for the youngest class of membership, following in this respect the practice of the Institution of Civil Engineers. But it must be remembered that the grade of 'Junior' in the American Society of Civil Engineers differs materially from that of 'Student' in the Institution. In the former, the members belong largely to a class who are not students in the common acceptance of the word; they are mostly young men who have completed a course of study in the technical schools, and are actually engaged in, or are prepared to engage in, the practice of the profession, while the latter are mostly young men still actually students under the apprenticeship system that prevails in England. The word Junior seems to the Committee to more appropriately represent the actual status of the young American engineer.

"It is recognized that there is a possibility of confusion in the minds of the public between the names 'Associate' and 'Associate Member,' which it might be desirable to avoid. But these names represent quite appropriately and accurately the two grades of membership as they are defined in the Constitution, and no other name or names have occurred to the Committee, or have been suggested to it, that seem equally germane, and at the same time less liable to misconception by the public.

"The name 'Member,' as representing the highest grade of corporate membership, is sometimes criticized because, in a broad sense, a person admitted to any grade of membership is a member of the Society, and confusion in the minds of the public is therefore possible. A number of substitutes for the name Member have been suggested and considered by the committee. None of them have seemed, upon the whole, to be more desirable or less

Report of Committee on Proposed Amendments to the Constitution (Continued).

objectionable than the simple word 'Member.' The danger of confusion and misconception is diminished by the fact that the corresponding grade is designated as 'Member' in all the national and in a great majority of the secondary engineering societies of this country, as well as by all the national engineering societies of England, so that it may be said that the parallel use of the name is practically universal among the English-speaking race. There seems to be no good reason why our Society should depart from the well established rule.

"In regard to qualifications for the several grades of membership the Committee thinks some changes are desirable both in the requirements and in the way they are defined.

"There seems to exist in the Society quite a strong sentiment in favor of raising the standard for admission to the grade of 'Member,' and in favor of making that grade represent more clearly a certain degree of honorable achievement in the profession, as well as a stated amount of professional skill and experience. The Committee, while feeling that any radical changes in this respect are inadvisable, believes that this sentiment tends in the right direction and should be respected. They therefore recommend that the age-qualification for admission as Member be raised to thirty-three years, and that the requirements for stated professional skill and experience be supplemented by a condition that the applicant shall have attained to some degree of honorable distinction in the profession. It is thought desirable that the Board of Direction shall be formally authorized to exercise some discretion in this direction, since it may occur that an applicant who can show compliance with formal requirements may nevertheless not have attained a position in the profession which would fully warrant his admission to the highest grade of corporate membership.

"For the same reasons it is thought desirable to formally empower the Board to take into consideration the character of the engineering work in the responsible charge of which the applicant has been engaged, in the case both of Members and Associate Members.

"The concluding clause of Sec. 5, Art. II, relating to the qualifications for the grade of 'Associate' has sometimes been held to exclude from that grade persons who have at any time or in any manner engaged in Civil Engineering work. This clause does not seem to be necessary or pertinent, and its omission is recommended.

"While the minimum age limit for Juniors is of little practical importance, it may be noted that young men are but very rarely qualified for admission to this grade before the age of 21. It seems more appropriate that the lower age limit should be that of the applicant's majority, and it is thought that a change from the present requirement (18 years) to twenty-one years would add somewhat to the dignity of the grade without impairing its usefulness to the class of young engineers for whom it is intended. The change is therefore recommended.

"The concluding clause of Sec. 2, Article III, requires that in the

case of engineers not resident in North America, members of the Board endorsing for them shall satisfy themselves 'that the applicant is worthy of admission.' While it may be safely presumed that the Board will continue to exercise all requisite care in these cases, it is thought prudent to supplement the language used by the requirement that the applicant must possess the qualifications for admission required of all others.

"Incidentally, the Committee has thought it desirable that our Constitution should more clearly define and accentuate the position which the Society has held from the first, that the profession of Civil Engineering covers the whole field of modern engineering and that its various subdivisions, such as mechanical, mining, and electrical engineering, are not separate and distinct professions, but branches of the parent profession.

"In conformity with the views outlined above, the Committee respectfully recommends that the Amendments referred to it be amended by substituting for them the following amendments to the Constitution:

"Strike out Sections 1, 2 and 3 of Article II, present Constitution, and substitute three sections, as follows:

"1. The Corporate Members of this Society shall be designated as Members and Associate Members. Corporate Members shall be Civil Engineers; the profession of Civil Engineering being here defined as including the branches commonly called Civil, Mechanical, Mining, Electrical, Military and Naval Engineering, and embracing Architecture and Naval Architecture. There may also be connected with the Society, Honorary Members, Associates, Juniors and Fellows, who shall be entitled to all the privileges of the Society except the right to vote and to hold office therein; provided that Honorary Members elected from the Corporate Members of the Society shall retain their right to vote and to hold office.

"2. A Member shall be, at the date of his admission, not less than thirty-three years of age; shall have been in the active practice of Civil Engineering for not less than ten years; shall have had responsible charge of engineering work of importance and merit for at least five years, and shall be qualified both to design and to direct engineering works. He shall also have attained a recognized position of honorable high standing in the profession. Graduation from a school of engineering of good standing shall be considered as equivalent to two years of active practice. The performance of the duties of professor in any of the branches of Civil Engineering in a technical school of high grade shall be considered as equivalent to an equal number of years of active practice.

"3. An Associate Member shall be not less than twenty-five years of age; shall have been in the active practice of Civil Engineering for not less than six years; and shall have had responsible charge of engineering work of creditable character for at least one year. Graduation from a school of en-

Report of Committee on Proposed Amendments to the Constitution (Continued).

gineering of good standing shall be considered as equivalent to two years of active practice. The performance of the duties of professor in any of the branches of Civil Engineering in a technical school of high grade shall be considered as equivalent to an equal number of years of active practice.

"Amend Section 5, of Article II, by striking out the final clause which reads: 'but who is not a professional engineer.'

"Amend Section 6, of Article II, by substituting, in the first sentence, the word twenty-one for the word eighteen. The sentence will then read: 'A Junior shall not be less than twenty-one years of age, and his connection with the Society shall cease when he becomes thirty-two years of age, unless he be previously transferred to another grade.'

"Amend Section 8, of Article III, by adding to the present Section the sentence: 'After December 31st, 1906, admission to the grade of Fellow shall be discontinued.'

"Amend Section 2, of Article III, final clause, by inserting after the word applicant, the words 'possesses the necessary qualifications and'. The clause will then read: 'to show that the applicant possesses the necessary qualifications and is worthy of admission.'

"Respectfully submitted by the Committee.

"S. Whinery,
"Alfred Noble,
"Onward Bates,
"Morris R. Sherrerd,
"Samuel E. Tinkham,
"Thaddeus Merriman."

Discussion on Proposed Amendments to the Constitution.

The President.—You have heard the report of the Committee, gentlemen. What is your pleasure?

It is moved that the report of the Committee be adopted, and that letter-ballots be ordered on the amendments.

I ask the Secretary whether, under the Constitution, the amendments do not go to ballot unless there is an amendment made here? I think we have to take no action whatever unless some amendment is made at this meeting.

The Secretary.—There does not seem to be any way by which a letter-ballot by the Society can be prevented.

Mr. Williams.—I would like to inquire whether, since the extension of the period for junior membership—I believe it has been extended, has it not?

The Secretary.—Yes.

Mr. Williams.—Has there been any action since that time to pass a Junior into the grade of Associate? The point I raise is this, that the grade of Associate was designed, as indicated by that closing paragraph, for men who are not engineers, and as such it was a highly honorable grade for a person to belong to; but, in the

course of events, it came about that persons were passed into it from the grade of Junior who had not yet acquired the standing necessary to make them Associate Members, and therefore the standing of that grade was materially depreciated, and the extension of the period of junior membership was made, I believe, with the intention of preventing that procedure; and, if that procedure is no longer necessary, it would seem to me well to retain that final clause in that grade, and let it be what it was originally designed for, a complimentary grade to those men who, although not practicing engineers, had achieved such prominence in their particular branch of science as to be worthy of association with the members of this Society, and I ask this question as to whether or not it is necessary to use that grade any longer as a stepping stone between the grade Junior and that of Associate Member?

THE SECRETARY.—I do not think that there is any such reason as that for that grade. I do not think there ever was. I think there were a few cases that were so transferred, but in each case the applicant was well qualified for the grade of Associate.

THE PRESIDENT.—Was it in recent years?

THE SECRETARY.—No; not in recent years. I think there were a few who could not be transferred to the grade of Associate Member, and who remained in the grade of Associate, but the question has usually come up in regard to the character of the work of the applicant, and there have been Juniors who were engineers, but whom the Board did not care to pass to the grade of Associate Member. Such men do not like to accept the grade of Associate when one of the requirements is that the candidate shall not be an engineer.

JAMES BURDEN, M. AM. SOC. C. E.—Mr. President, I have always understood that the original engineers were military men. They built roads to facilitate the movement of troops. In time, other roads were required, for commercial purposes, and they were constructed by civilians who were distinguished as civil engineers. If this be the case, it is manifestly absurd to speak of military engineering as a branch of civil engineering, and the term, if it be retained in the amendment, should be placed with architecture and naval architecture, which are not declared to be among the "several branches" of civil engineering.

RUDOLPH P. MILLER, M. AM. SOC. C. E.—It seems to me that three classes ought to be sufficient to include all engineers: Members, Associate Members and Juniors. I have always understood that the Associate is to include such as simply had some connection, or some interest in engineering work and were not engineers, and it seems to be desirable, instead of including architects or marine architects in the regular membership or corporate member-

Discussion on Proposed Amendments (Continued).

ship of this Society, they would naturally fall into that class of Associate. I think, as one of the speakers suggested, that it would give the grade of Associate a more dignified standing than it has if we admit other engineers to this grade. I think it would be a mistake to include architects. There are a great many architects who have attained eminence in their profession, and are not qualified for membership in this Society.

HENRY GOLDMARK, M. AM. SOC. C. E.—It seems to me that the last point, in regard to architects and possibly in regard to some other kindred professions, is very well taken. I know that architects would be naturally more likely to join the Associate rather than the engineer grade; and, as a matter of fact, I happen to know that in a few cases architects have been admitted as Associates in the Society rather than as engineers, presumably from a feeling of the Board that they did not want to admit them as full-fledged Members of the Society, although to elect an architect of standing and mature age as an Associate Member was not really classing him where he belonged; and that a class of Associates—persons belonging to the kindred professions—would be more dignified and usually more desirable for the persons in question.

MR. MARBURG.—The report of this Committee has not been set up in printed form?

THE PRESIDENT.—It has not.

MR. MARBURG.—Under those circumstances, it seems to me it would be desirable to postpone action by passing a vote now on the contents of this report, especially in view of the fact that differences of opinion are being developed, until the printed report can be sent to the members.

JOSEPH M. KNAP, M. AM. SOC. C. E.—I move that all the members of the Society have an opportunity to vote for it or against it, and it seems to me unnecessary to postpone this matter.

E. L. VERVEER, ASSOC. M. AM. SOC. C. E.—When the members have an opportunity to vote on the printed ballot there may be some parts of the amendment to which they object, and therefore it would be impossible for them to express their opinion on those amendments; therefore, I think it is not wise to send out a ballot for vote, but is much wiser to send out the printed forms for discussion and to gain the opinions of the different members of the Society.

MR. MARBURG.—Is there a motion before the meeting?

THE PRESIDENT.—No.

MR. MARBURG.—I move that the report of this Committee be printed and sent to the membership at large with a view of eliciting their opinions, and with a view that at a future meeting of the Society, according as the Constitution or the Board of Direction may determine——

THE PRESIDENT.—I think that motion is hardly in order. The Secretary will read the portion of the Constitution relating to the action that may be taken by this meeting.

(The Secretary read Sections 2, 3 and 4 of Article IX of the Constitution.)

"2.—Amendments presented to the Secretary on or before the first Wednesday in November shall be sent by letter to the several Corporate Members of the Society at least twenty-five days previous to the Annual Meeting. Such amendments shall be in order for discussion at such Annual Meeting, and may be amended in any manner pertinent to the original amendments by a majority vote of the Annual Meeting, and if so amended shall be voted upon by letter-ballot in form as amended by the Annual Meeting; if not so amended, they shall be voted upon by letter-ballot as submitted. The vote to be counted at the first regular meeting in March.

"3.—Amendments presented to the Secretary not less than sixty days previous to the date of the Annual Convention shall be sent by letter to the several Corporate Members of the Society at least twenty-five days previous to the Annual Convention. Said amendments shall be in order for discussion at the Business Meeting during such Annual Convention, and may be amended in any manner pertinent to the original amendments by a majority vote of the Business Meeting during the Annual Convention, and, if so amended, shall be voted upon by letter-ballot in form as amended by said Business Meeting; if not so amended, they shall be voted upon by letter-ballot as submitted. The vote to be counted at the first regular meeting in October.

"4.—If, after discussion of a proposed amendment, at either of the general meetings of the Society, the meeting shall so decide by a majority vote, it may refer the amendment to a Committee for further consideration, which Committee shall report at the next general meeting, whereupon the amendment shall be voted upon as hereinbefore provided."

THE PRESIDENT.—As I understand the Constitution, this amendment was submitted at the Annual Meeting and was by that meeting referred to a committee.

THE SECRETARY.—Yes; that is true.

THE PRESIDENT.—And has to be acted upon at this meeting, or if not acted upon goes out for a letter-ballot.

JOHN F. O'ROURKE, M. AM. SOC. C. E.—Would it not be better, considering the character of these amendments, to wait for action until such time as the membership is fully informed; in other words, postpone it until the next Annual Meeting? Would that be in order?

THE PRESIDENT.—I think that is not in order, as I understand the Constitution. It might be a very proper thing to do, but it is not so prescribed.

MR. O'ROURKE.—I would consider it very dangerous to vote in

Discussion on Proposed Amendments (Continued).

favor of any such amendments, simply because the Constitution requires them to be voted upon, without consideration.

THE PRESIDENT.—The Chair would be very glad to receive that motion if it were not that he understands that it is not permitted by the Constitution.

T. L. CONDRON, M. AM. SOC. C. E.—In view of the fact that some action must be taken at this meeting, I would make a motion that the report of the Committee that has been read be printed and distributed at this meeting, and the subject be postponed for further discussion and consideration until the last meeting of this Convention, which occurs on Friday morning of this week.

THE PRESIDENT.—Was that motion seconded?

(Motion seconded.)

MR. CONDRON.—The Assistant Secretary advises me that it will be difficult to get this report printed at this meeting. Maybe it would be possible to get a few typewritten copies of it for circulation; if not, I am willing to modify my motion that it may be brought up at the final meeting of the Convention.

THE SECRETARY.—I think we can get it printed.

MR. CONDRON.—Then I will move it as before; it has been moved and seconded.

A. N. TALBOT, M. AM. SOC. C. E.—There are a number of us who still fail to see why the postponement of action may not be taken, under the Constitution. I believe it is a matter of Parliamentary law that postponements are in order, and, from that point of view, one hardly expects that this provision of the Constitution would go on to say that action should not be taken at that time. It appears to say, if action should be taken, it does not specify that the ordinary action of Parliamentary law shall not be taken. It seems to me that it would be much wiser to postpone this until the Annual Meeting and let the matter go over to the Board of Direction.

THE PRESIDENT.—The Chair will reverse its ruling. I think that the Constitution is a little blind in that part, and I will rule, if it be so permitted by the assembly, after another motion is made, that this matter can be recommitted.

MR. MILLER.—I move to recommit the proposed amendment for further consideration and report at the Annual Meeting.

THE SECRETARY.—If I might make a suggestion, I would add to that motion that the Secretary be instructed to send out this report for the information of members as soon as possible.

MR. O'ROURKE.—As I understand it, the objection to considering this matter is that the Committee has reported and the membership has not been informed as to the report. While it might be well to recommit it, it would be useless to have it recommitted for consideration at the next Annual Meeting, for the reason that the report

will be just as enigmatic then as it is now. I suggest that this report be considered at the Annual Meeting and not be recommitted. My only feeling is that the feeling among the membership is that we want to consider this matter after it has left the Committee's hands. If it is recommitted, it will be necessary to postpone it again, as it is now.

THE PRESIDENT.—I think, in answer to the last statement, that the only thing that can be done practically is to recommit it. It will be recommitted with instructions. That is one of the ways that a report could be handled, and if recommitted it can nevertheless be printed and sent out, and the Committee can report the same amendments at the next meeting.

MR. O'ROURKE.—I have been a member of the Society for more than twenty years. There were reports considered the year I came in and they have not been finished yet. Whether they were talked to death or laughed to death, I do not know.

MR. WILLIAMS.—It seems to me, if a motion to recommit is to be made, it should not be done until there has been a little more discussion of the report as it stands. Let us have a chance to discuss it, and let us have a chance to say something about it on Friday. It seems to me that this meeting is quite representative of the membership of the Society. It seems to me that those present are as able to speak on the matter of membership qualifications as any crowd we are likely to get together, and it would be a misfortune to go away without discussing it. When we get home we will read these propositions in the letter-ballot; we will read them through and perhaps be more in accord with them, but it may be doubted whether we would express ourselves as freely as we would when we are stirred by the thoughts of others.

MR. KNAP.—This motion to recommit is the very best way out of it. That would let us out constitutionally; and, as to putting it off until Friday, a good many of us will not be here on Friday. The idea of discussing it further here is a very good one, before we drop the subject, and then have it taken up at the next meeting.

THE PRESIDENT.—The Chair rules that a motion to put it off until next Friday would take precedence of a motion to recommit, for the reason that the motion to recommit could be carried next Friday if desirable. At the same time, the motion before the meeting is the motion to recommit.

MR. VERVEER.—My motion would be to put it off until Friday, and the second would be a motion to recommit.

THE PRESIDENT.—That is correct. I did wish to make that ruling that it might be recommitted because I had previously ruled otherwise. It was not in order to allow the motion to recommit, in view of the other motion being before the meeting and granted, and

Discussion on Proposed Amendments (Continued).

therefore I shall state that the motion now before the meeting is the one to defer the matter until next Friday, the amendment to the Constitution to be printed in the meantime, if possible, and circulated.

MR. TALBOT.—I would like the privilege of asking how the Chair would rule on a motion to make this report a special order for the Annual Meeting, with instructions to the Secretary to have the matter printed and sent out to the membership, and whether there is anything in the Constitution, in the provision which was read, which would exclude that. There may be nothing which will specifically permit it, but I do not think there is any other that will specifically——

THE PRESIDENT.—The Chair saw that there was a chance to recommit, under the Constitution. There might, under some general rule, be a possibility of doing what is suggested, but I would rule that it cannot be done, and the motion before the meeting is the one to defer the matter until next Friday.

WILLIAM B. FULLER, M. AM. SOC. C. E.—Before this motion is put, I would like to hear from Mr. Trautwine, as I understand that he has a minority report.

THE PRESIDENT.—I think it is very proper to have that minority report at the present time, so that we should have that report before us.

JOHN C. TRAUTWINE, JR., ASSOC. AM. SOC. C. E.—As I remember, there was no difference of opinion whatever between the majority of the committee and myself as to any essential or vital matter in the report. The differences between us are simply verbal; and there is this difference, also, that the majority of the committee is under the impression that these differences are of minor importance, while I am inclined to think them of considerable importance, and I think this is a very favorable opportunity to get it into shape.

A telegraph operator once sent a message in reply to an inquiry as to the credit of a certain man. The telegram was: "Not good for any amount," and the operator carelessly put an "e" at the end of the word "not." He protested that it was a very trifling mistake, but those who received the message with the addition seemed to think that it made a considerable difference.

I think there is unanimity among the Committee respecting the matter of the amendments, as suggested. With regard to all matters of principle and of policy, I think I have the honor to be in entire accord with my fellow-members of the Committee. Especially do I agree with them respecting the very radical letting down of the bars, involved in the amendments as first submitted. These amendments did away with all requirements as to length of service in the profession, and as to other qualifications, and required only that the applicant should have acquired a certain standing.

I heartily agree with my fellow-committeemen that the requirement of "recognized high standing" should be incorporated in the Constitution, not as a substitute for existing requirements, but in addition to them.

I differ with my fellow-committeemen only as to the advisability and importance of certain amendments, chiefly if not wholly rhetorical, which I venture to submit, to the Committee's proposed amendments; but these suggestions of mine are such that I can best present them by submitting a proposed new reading for Article II.

I think there is unanimity in the Committee respecting the mattter of the amendments, as suggested, which provide that a member shall be a civil engineer who shall have reached a position of recognized standing in the profession, etc., that amendment doing away with all the clauses providing for a certain number of years of experience and leaving it entirely to the discretion of the Committee as to whether a man has a reputable standing.

It seems to me now, and it seemed to me then, that under such an amendment a good-natured or easy-going Membership Committee might admit to membership a person for instance like myself; and that there should always be a restriction as to the length and importance of the services; but the Committee has also agreed that there should be this additional qualification, that the engineer member of the Society should have reached a position of recognized importance.

As I wrote to Chairman Whinery:

"I much regret to find that in taking the matter up again, and going over the proposed report, the suggestions I have to offer are such that I can best accomplish this by submitting for your consideration an entirely new draft for Art. II, which I enclose herewith, and upon which I beg to remark as follows, referring to the several sections by number."

There are some radical verbal changes here. Article II, membership:

"Membership in the Society shall be restricted to persons following the profession of Civil Engineering, in any of its several branches, including Mechanical, Mining, Marine and Electrical Engineering, Architecture and Marine Architecture.

"The members of the Society shall be classified as follows: Honorary Members, Seniors, Juniors, Associates, Students.

"The Seniors and the Juniors shall comprise the Corporate Membership of the Society. They alone shall have the right to vote and to hold office therein; but when a Corporate Member is made an Honorary Member, he shall not thereby forfeit his right to vote and to hold office.

"A Senior shall be, at the date of his admission as such, not less than thirty-three years of age; he shall have been in the act-

Discussion on Proposed Amendments (Continued).

ive practice of Civil Engineering for not less than ten years; he shall have had responsible charge of engineering work of importance and merit for at least five years, he shall be qualified both to design and to direct engineering works, and he shall have attained a recognized position of honorable high standing in the profession.

"A Junior shall be, at the date of his admission as such, not less than twenty-five years of age; he shall have been in the active practice of Civil Engineering for not less than six years and he shall have had responsible charge of engineering work of creditable character for at least one year.

"In considering the qualifications of candidates for admission as Seniors or as Juniors, graduation from a school of engineering, of good standing, shall be considered as equivalent to two years of active practice. The performance of the duties of professor in any of the branches of Civil Engineering, in a technical school of high grade, shall be considered as equivalent to active practice.

"Any person having the necessary qualifications prescribed in this article to entitle him to admission to the grades of Senior or Junior, shall be eligible for such membership, though he may not be practicing his profession at the time of making his application.

"An Associate shall be a person who, by scientific acquirements or by practical experience, has attained a position in his special pursuit qualifying him to co-operate with engineers in the advancement of professional knowledge and practice but who is not qualified for admission as a Senior or as a Junior.

"A Student shall be, at the time of his admission to the Society not less than twenty-one years of age, and his connection with the Society shall cease when he becomes thirty-three years of age, unless he has been previously transferred to another grade. He shall have had active practice in some branch of engineering for at least two years, or he shall have graduated from a school of engineering of recognized high standing.

"Honorary Members shall be chosen only from persons of generally acknowledged eminence in some branch of engineering or of the sciences related thereto. There shall not be more than twenty Honorary Members at any one time.

"After June 30th, 1906, admission to the grade of Fellow shall be discontinued.

"The adoption of this Article of the Constitution shall not affect the status of any persons who shall be Members or Fellows of the Society at the time."

Writing to Mr. Whinery, in advance of the suggestions here proposed I said, with regard to the first clause:

"It seems to me well to insert a word such as 'restricted,' implying not only that members shall be thus and so, but also that no others shall be admitted. This, of course, amounts to the same thing, but it seems to me that we make it more definite by putting it in this negative and prohibitory form.

"It has only recently occurred to me that the attempt to make Civil Engineering include Military and Naval Engineering is historically incorrect.

"If I understand rightly, the term 'Civil Engineer' was invented for the purpose of designating those few and inconspicuous individuals, who, at that time, had the hardihood to apply the science and art of engineering to useful purposes, in order to distinguish them from 'the engineer' who devoted them solely to destructive purposes.

"We cannot therefore properly speak of Civil Engineering as including Military and Naval Engineering. This would be a contradiction in terms.

"On the other hand it might now well be questioned whether there is such a thing as a military engineer or a naval engineer. True, there are civil engineers (marine, mechanical, electrical, etc., etc.) who apply their knowledge of civil engineering to military uses, but their engineering, it seems to me, is none the less civil. The man who designs and constructs a machine gun is a mechanical engineer, even though it suits his convenience to use his ability in the line of destruction.

"This being the case, I should feel disposed, if I did not feel that I were already quite radical enough, to suggest the dropping of the word 'civil' as superfluous, and calling the Society simply 'The American Society of Engineers."

"(2) I cannot agree with the Committee that the ambiguity in the use of the word 'Member,' to signify (1) any member, and (2) a certain class of members, is a small and unimportant matter. Whether or not this misuse of the term is liable to lead to serious misunderstanding may be questioned, but certainly I think we should not be willing to be found guilty of such abuse of language.

"That our English friends commonly misuse the term in the same way counts for little, as the English are, I think, the most careless of writers, with the possible exception of the Americans.

"As you will notice, the names which I suggest for the four classes of members, other than Honorary Members, recall the names given to the four corresponding classes in our universities, the names 'Senior' and 'Junior' being retained for 'Member' and 'Associate Member,' respectively, while 'Sophomore' and 'Freshman' are exchanged for 'Associate' and 'Student,' respectively.

"The objection, mentioned by the Committee, to the use of the word 'Student' for the lowest class, seems to be well taken, but the members of this class may properly be considered as students, relatively to those in the other classes, and I submit the term provisionally, for want of a better one.

"(4). I suggest the insertion of the words 'as such,' inasmuch as it is manifestly not intended that the Senior shall necessarily be thirty-three years of age at the time of his admission to membership in the Society, which might be an admission to one of the lower grades.

"(5). A similar remark applies respecting the insertion of the words 'as such' (in the next clause).

"(6). In the report of the Committee, these stipulations are repeated under the qualifications for admission as Member and as Associate Member. This repetition seems unnecessary, and I have therefore placed these stipulations in one paragraph by themselves."

Discussion on Proposed Amendments (Continued).

The original Constitution reads that performance of the duties of professor in an institution or a university shall be considered equivalent to active practice, and I think that is in correct form.

Mr. Merriman, Secretary of the Committee, recommends in the report the reinserting of the words "an equal number of years of" instead of "the performance of duties"; making it read, "shall be considered as equivalent to an equal number of years of active practice"; which seems to me incorrect in form.

When we say, if we could say, that the strength of steel is equal to the strength of wrought iron, it would be wrong to say that the strength of steel is equal to a certain number of square inches of wrought iron.

"As I have now put it, the performance of duties is to be considered equal to active practice, and that, I think, is as it should be. If we were going to insert a provision as to years, we ought to say: 'The performance of the duties, etc., etc., for any given number of years, etc., etc., shall be considered as equivalent to an equal number of years of active practice.'

"(8). I cannot agree with the Committee that the mere omission of the words 'but who is not a professional engineer,' in Sec. 5 of the present Constitution, would be a satisfactory amendment to that section, because the qualifications therein set forth for the Associate, would be those of every Member and Associate Member.

"I therefore suggest the substitution, for 'but who is not a professional engineer,' of the words 'but who is not qualified for admission as a Senior or as a Junior.'"

I regret to note a disposition in some part of the meeting to squeeze this grade out. That thing nearly happened to me once before, many years ago, when it was suggested that because I had had the hardihood to undertake some small matters of engineering work, I should therefore be excluded from the grade of Associate, so that there was no place for me, and I speak feelingly for those who are not qualified to become Members, but who may have jeopardized their standing by doing some engineering work which would disqualify them for becoming Associates. I therefore maintain that an Associate should be one who is qualified to co-operate although he may not be qualified to become a Member of or an Associate Member.

"(9). It seems to me that inasmuch as the age for admission as a Member is to be made thirty-three years, that for the termination of Juniorship should be made thirty-three years also."

Mr. Whinery has since suggested that there is a special reason for allowing one year and that is to compel Juniors to pass through the Associate Member grade, or rather to prevent jumping from Junior to Member.

"(11). I see no reason why admission to the grade of Fellow should not be discontinued as soon as possible after adoption of amendments to the Constitution."

But Mr. Whinery has reminded me that it may be months before the thing is put through, so it seems that it had better remain as it is.

"Sec. 6 of the Constitution, as printed, and as amended by the Committee, contains the clause 'persons who are in the Junior class at the time of the adoption of this Constitution shall not have their status changed by the provisions of this section.' It seems to me that there should be a section, such as I have here submitted, making similar provision covering all the classes of membership and especially Fellows.

"Incidentally, I have striven to put the wording of Article II in concise form, and to reduce, as far as possible, the number of words used, while, at the same time, making the meaning as clear as I could.

"While, as the report of the Committe states, there is a possibility of confusion in the minds of the public between the names 'Associate' and 'Associate Member,' such confusion, if it arises, must be the fault of the public mind, and not of the terms used; for although they both contain the same word, 'Associate,' the use of the word 'Member' in connection with one of them relieves the Constitution of the charge of ambiguity; but the use of one and the same term, 'Member,' to express two radically different ideas, is in itself faulty, and should be avoided.

"It states that 'there seems to be no good reason why our Society should depart from the well established rule,' but, as I have already remarked, it seems to me eminently fit that the American Society of Civil Engineers should embrace the opportunity, act as pioneer, and set a good example to our English brethren of the use of the English language."

HENRY B. SEAMAN, M. AM. SOC. C. E.—I think these notes ought to be included with the main report. After being referred back, it should be placed before the whole Society for final consideration, just as the main report should be considered.

D. E. MCCOMB, M. AM. SOC. C. E.—I think I noticed, that requirement for Membership states that the applicant must have attained a certain degree of prominence in Civil, Mechanical, Mining and Electrical Engineering. It seems to me that there are very few who have attained prominence in all of these.

MR. TRAUTWINE.—That, I think, was carefully considered by the Committee.

THE PRESIDENT.—The question is as to the adoption of the motion that this matter be postponed to a Business Meeting to be held on Friday morning.

J. W. ALVORD, M. AM. SOC. C. E.—May I ask would it be possible to have the printing done any earlier than Friday morning?

Discussion on Proposed Amendments (Continued).

THE SECRETARY.—It may not be possible to do it by Friday morning, but the Secretary will do his best, and have all the printing presses in Clayton at work as soon as possible.

THE PRESIDENT.—I think the other days are taken up, I am not sure. The question is on the motion to postpone this matter until next Friday morning. Those in favor of the motion will say "aye;" those opposed, "no."

A division is called for. Those who are in favor of the motion will please stand until they are counted.

THE SECRETARY.—Forty-four.

THE PRESIDENT.—Those opposed.

THE SECRETARY.—Thirty-seven.

THE PRESIDENT.—The motion is carried.

MR. WILLIAMS.—I did not hear the decision. I would like to move, in view of the fact that there is a possibility—that it may not be possible to have this report printed, that a copy of the report and also of Mr. Trautwine's report—I do not mean his letter but simply his proposed draft of amendments—be posted in the room of the Secretary, or elsewhere about the hotel, that Members may have an opportunity to consult it between now and Friday morning.

THE SECRETARY.—In order to be available by Friday we have to get the only copy that is here over to the printing office to-day. There will be another copy here to-morrow, I think.

THE PRESIDENT.—I think there is no occasion for voting on that point. The matter will be attended to, if possible. The next matter is a resolution recommending the appointment of a Special Committee on the Metric System. The Secretary will read the resolution.

Appointment of a Special Committee on the Metric System.

(The Secretary read the resolution and recommendation of the Board as follows):

"*Resolved*, That a Special Committee be appointed to collect such information as may be obtainable on the present and prospective status of the adoption of the metric system in the United States, and to collate and systematize such information and promulgate it to the Society in form of reports from time to time."

"At a meeting of the Board, June 5th, 1906, it was resolved that the Board recommends to the Society the appointment of a Special Committee, as called for in the resolution.

"The arguments in favor of the appointment of such a Committee being that some information may be transmitted through such Committee to the Society, and that no harm can be done by the appointment of such a Committee.

"There does not seem to be any argument against the appointment of such a Committee."

THE PRESIDENT.—The Secretary will read the provisions of the Constitution relating to the adoption of resolutions of this kind.

THE SECRETARY (Reading):

"Article VI, Section 12: Special committees to report upon engineering subjects shall be authorized only by a majority of the votes cast by the Society, and in the following manner: A proposition to appoint such a Committee shall be presented at a regular meeting of the Society, and if sustained, on a motion to refer the same to the Board of Direction, by an affirmative vote of not less than twenty-five Corporate Members, it shall be so referred."

THE PRESIDENT.—This matter is open for discussion.

M. J. RIGGS, M. AM. SOC. C. E.—I move that the resolution be adopted.

THE PRESIDENT.—You have heard the motion and the resolution of the Board in regard to the appointment of the Committee on the Metric System; that is, that it will be sent out for a letter-ballot. Those in favor of the motion will say "aye."

(Carried unanimously.)

THE PRESIDENT.—The next matter is a report as to the Society House.

(The Secretary read the following report in reference to the Society House:)

Report on the Society House.

## GENERAL STATEMENT RELATING TO THE SOCIETY HOUSE, PREPARED FOR THE INFORMATION OF THE 38th ANNUAL CONVENTION.

"The Secretary has prepared a brief statement as to the Society House which may be of interest to the Convention.

"The project for the building of the original Society House was authorized at the Annual Convention, June 20th, 1895. Two lots, Nos. 218 and 220 West 57th Street, were purchased in January, 1896, and the building erected thereon was completed and occupied by the Society in November, 1897.

"Owing to the fact that the Entrance Hallway, Auditorium and Lounging Room were unequal to providing comfortably for the increasing attendance at Annual Meetings, the Board of Direction decided, early in 1904, to purchase more ground.

"An additional lot (25 ft. frontage) was purchased on June 6th, 1904, at a cost of $100,000, and a contract for the erection of an addition covering it was let on May 2d, 1905. The building was so far completed that it was used at the Annual Meeting on January 17th, 1906.

"With the exception of the decoration, the new part of the building (which adds 50% to the size of the original house) is now complete. Its total cost, including lighting fixtures and Architects' fees, has been $61 338.30. Its decoration will be taken up as soon as the walls have thoroughly seasoned, and it is the intention to redecorate the old part of the house at the same time.

"The property of the Society now consists of a plot (Nos. 218, 220 and 222 West 57th Street) of 75 ft. frontage on 57th Street, 106 ft. 11 in. deep on the easterly side, 117 ft. 11 in. on the westerly

Report on the Society House (Continued).

side, containing 8 431 sq. ft., with a building of 4 stories and basement on the front part of the lot, and of 2 stories and basement covering the rear portion.

"The following table shows the floor space and cubic contents of the building, together with the amount of each devoted to the various uses connected with the Society's work. The figures given include thickness of walls and floors:

| | Area, in Square feet. | Contents, in Cubic feet. |
|---|---|---|
| "Secretary and General Office Force..... | 3 804 | 44 693 |
| Mailing and Storage Rooms..... | 5 475 | 60 258 |
| Reading Rooms ..... | 2 584 | 42 213 |
| Auditorium and Lounging Room..... | 7 038 | 143 635 |
| Board Room ..... | 456 | 6 083 |
| Stack Rooms ..... | 3 281 | 55 785 |
| Reception Hall, Main Hall, Stairways, etc. ..... | 3 877 | 57 164 |
| Coat, Toilet and Service Rooms..... | 1 005 | 13 981 |
| Engine Room, Coal Vaults, Area (under sidewalk). ..... | 2 250 | 28 125 |
| Janitor's Quarters ..... | 1 628 | 21 715 |
| Total ..... | 31 398 | 473 652 |

| | | |
|---|---|---|
| "The total cost has been as follows: | | |
| Lots and Vault privileges..... | $180 937.50 | |
| Building and Furniture..... | 189 332.52 | |
| | | $370 270.02 |
| Present Mortgage and Loan..... | | 178 000.00 |
| Cost above debt..... | | $192 270.02 |

"It is estimated, however, that the plot (without building) owned by the Society is worth at the present time at least $270 000, and on this basis, omitting all items of furniture included in the above statement, the assets of the Society, so far as its real estate holding is concerned, are about $275 000.

"Respectfully submitted,
"CHARLES WARREN HUNT,
*"Secretary."*

"NEW YORK, June 20th, 1906."

Erection of a Bronze Tablet at Washington University.

THE PRESIDENT.—There is also a report from the Secretary as to the erection by the Society of a tablet commemorative of the International Engineering Congress at St. Louis, in 1904.

(The Secretary read the following report):

**BRONZE TABLET.**

"Some time ago the Board of Direction authorized the expenditure of a proper amount for the erection of a Bronze Tablet in Washington University to commemorate the International Engineering Congress, St. Louis, 1904.

"The tablet has been designed, and has been cast by the Sterling Bronze Company, under the direction of Cope and Stewardson, Architects for the University. The tablet is about 2 ft. 9 in. square, and contains the following inscription:

THIS TABLET IS

ERECTED BY THE

AMERICAN SOCIETY OF CIVIL ENGINEERS

TO COMMEMORATE THE

INTERNATIONAL ENGINEERING CONGRESS

HELD UNDER ITS AUSPICES

IN THESE BUILDINGS OF

WASHINGTON UNIVERSITY

OCTOBER 3RD TO OCTOBER 8TH

1904

"The Tablet has been accepted, and delivered to the University, but up to the present date information has not been received that it has been set in place."

THE PRESIDENT.—The Secretary has some announcements to make.

THE SECRETARY.—The Secretary, some days ago, received the following note:

Letter from Mr. and Mrs. Charles Macdonald.

"Mr. and Mrs. Charles Macdonald request the honour of meeting the Members of the American Society of Civil Engineers and their Guests at Luncheon on Wednesday, June 27th, 1906, at one o'clock.

"Blinkbonny, Gananoque."

"To CHAS. WARREN HUNT, Esq.,
"SECY., AMERICAN SOCIETY OF CIVIL ENGINEERS,
"220 W. 57TH ST.,
"NEW YORK."

Announcements as to Programme, etc.

THE SECRETARY.—Arrangements have been made, as you have seen by the programme, for accepting this invitation of Mr. and Mrs. Macdonald, and the steamer will start at 11.30 A. M. for Gananoque, Canada, and, after the members have had luncheon at Mr. Macdonald's, will leave that place at about 3 P. M., and continue the sail down the Canadian side, returning *via* the American Channel, and reaching this hotel at about 6 o'clock.

Those members who have brought their clubs with them will find an announcement of the details of a Golf Tournament in the office at the close of this meeting.

I would like to announce that there will be a meeting of the

Announcements (Continued).

Board of Direction this evening in the parlor at the end of the hall, after the close of the President's address.

Members who have certificates of having paid their one-way fare should turn their certificates in as soon as possible at the Secretary's office accompanied by 25 cents. It is necessary that this should be done promptly in order that the agent who comes here to visé the tickets shall have them as soon as possible.

I would like to call attention to the fact that while a motion has been proposed here to print a document to be presented at a meeting which has been scheduled for Friday, that no such meeting has been scheduled, and that this is the Business Meeting of the Annual Convention. It seems to me that the proper procedure is that this Business Meeting should adjourn as a Business Meeting to some hour on Friday morning, and I suggest Friday at 10 A. M.

MR. WILLIAMS.—I move that when the meeting adjourns that it meet again at ten o'clock on Friday in this room.

THE PRESIDENT.—You have heard the motion that when this meeting adjourns, it adjourns to meet on Friday morning in this room.

MR. CONDRON.—I suggest that the Business Meeting might adjourn subject to the call of the President. That might not be until Friday morning. I move that it adjourn subject to the call of the President.

THE PRESIDENT.—The motion as amended is that when the meeting adjourn, it adjourn subject to the call of the Chair.

(Motion duly seconded.)

THE PRESIDENT.—I will put that motion.

(Motion carried unanimously.)

Resolution of Thanks to Mr. Macdonald.

F. R. COATES, ASSOC. AM. SOC. C. E.—I move that Mr. Macdonald's invitation for luncheon to-morrow be accepted, and that the members present extend to Mr. Macdonald, through the Secretary, their thanks for this kind invitation.

MR. O'ROURKE.—I second that motion. I trust that everybody will appreciate the spirit in which this invitation is extended.

THE PRESIDENT.—Those in favor of the motion will say "aye."

(Motion carried unanimously.)

THE PRESIDENT.—It is moved and seconded that we adjourn.

(Adjourned.)

## ADJOURNED BUSINESS MEETING.

Adjourned Business Meeting Called to Order.

**Fourth Session.**—The fourth session of the Convention was called to order on Wednesday evening, at 8.30 o'clock, President F. P. Stearns in the chair; Charles Warren Hunt, Secretary, and present, also, about 90 members.

THE PRESIDENT.—The meeting will please come to order. This is an adjourned Business Meeting, and the matters to be taken up, so far as known, are a resolution proposed at one of our other meetings, in regard to a Committee on Engineering Education—I do not know the exact terms—the other matter is the proposed amendments to the Constitution. If it is the pleasure of the meeting, we will take up the question of the Committee first. Mr. Marburg made the suggestion originally.

Proposed Special Committee on Engineering Education.

MR. MARBURG.—I proposed the following resolution: *Resolved,* That it is the sense of this meeting that a Committee be appointed to report on the status of Engineering Education in this country, and to recommend measures calculated to place it on the highest plane of efficiency.

MR. WILLIAMS.—I would like to suggest that the word "Special" be inserted before Committee, instead of simply "A Committee." That does not appear there. It seems to me that it should; and I will then second the motion.

THE PRESIDENT.—Is that accepted by the mover of the resolution?

MR. MARBURG.—That amendment is accepted.

THE PRESIDENT.—The Secretary will read the resolution.

THE SECRETARY.—*Resolved,* That it is the sense of this meeting that a Special Committee be appointed to report on the status of Engineering Education in this country, and to recommend measures calculated to place it on the highest plane of efficiency.

Discussion on Proposed Special Committee on Engineering Education.

THE PRESIDENT.—You have heard the motion. The matter is now open for discussion.

ANDREW BELL, M. AM. SOC. C. E.—Might I ask, does that include Canada as well as the States?

THE SECRETARY.—"This country," it says in the resolution.

MR. WILLIAMS.—Perhaps it may be proper for me to say a word or two on that resolution, in order to clear up any haziness there may be in the minds of those here. The feeling of the few of us who are so unfortunate as to be entrusted with the education of the coming engineers of the country is that we need the co-operation and advice of those men in the profession who are represented by the membership of this Society. We feel that our engineering schools should be in closer touch with the profession whose rights they are supposed to guard, and we hope that this Society may see fit to take up this question and consider it in all sincerity; and as a result of this work there may be further improvements, and very possibly great improvements, in the standing and efficiency of engineering instruction.

We have not in mind any specific scheme to be carried out, but wish to entrust that to the members of the Society who may be

Discussion on Proposed Special Committee on Engineering Education (Continued).

selected for the Committee when the time comes to select it, and in whose labors we can certainly expect to find very much that will be of value, even though they should not reach the ultimate ideal that some may have in mind concerning it.

THE PRESIDENT.—Any further remarks?

MR. CONDRON.—There is no set time in the resolution for the Committee to report?

THE PRESIDENT.—It is only the sense of the meeting that such a Committee should be appointed. That would not be necessary at the present time. You have heard the motion, gentlemen.

(Motion seconded by Mr. Owen.)

THE PRESIDENT.—Those in favor of the motion will say "aye"; those opposed, "no."

(The motion was carried.)

MR. WILLIAMS.—I move that this resolution be referred to the Board of Direction for consideration.

(Motion seconded by Mr. Talbot.)

THE PRESIDENT.—The Secretary suggests to me that I ask whether you mean "under the provisions of Article VI, Section 12, of the Constitution"?

MR. WILLIAMS.—I intended to include that in the resolution.

THE PRESIDENT.—That is the section of the Constitution which provides for the appointment of Special Committees of the Society. Are there any remarks on this motion? If there are not, I will ask those in favor of it to raise their right hands until they are counted.

THE SECRETARY.—Forty-seven.

THE PRESIDENT.—Only 25 votes are required by the Constitution, and as there are 47 in favor, the motion is carried.

MR. RIGGS.—The negative vote is not called for?

THE PRESIDENT.—I will put the negative if so desired. Those opposed will raise their right hands.

THE SECRETARY.—None.

Discussion on Proposed Amendments to the Constitution.

THE PRESIDENT.—The motion is carried. The next matter is the proposed amendment to the Constitution. The report of the Committee on the proposed amendments—or the amendments proposed by the Committee—is printed. The Secretary will pass copies around if they are not already in the hands of the members. I understand that there was not time to have printed the report of the minority.

MR. SHERRERD.—Mr. President, I regret that I seem to be the only member of the Committee who is present at this meeting, because I know there are several members of that Committee who could present this subject in a much more forcible and more graceful manner. However, I feel that I am somewhat entitled to speak on this particular question of the suggested amendments because,

in a measure, I was one of the instigators of the suggestion that the amendments—or the particular amendment to elevate the grade of membership—should be considered by the Society.

I would like to say that those amendments, as embodied in the printed slip, received the careful consideration of the entire Committee, either through being present at the three or four sessions of that Committee which have been held since the January meeting, or by correspondence from the Secretary of the Committee to each member of the Committee. I regret that the printed slip which has been passed around does not also contain the suggestions of the Minority Report. I understand that the reason for this is that there was not time to print the latter.

As for the verbal changes suggested by the Minority Report, it is perhaps only fair to the Committee to say that the final report was practically agreed upon at a meeting at which the member of the Committee who presents the Minority Report was not present, and that these suggestions were no doubt mailed to that member of the Committee at the time they were mailed to the other members. However, the Committee would not, as I understand from the feeling expressed, have refused to consider such verbal changes as were suggested, which were in the line of a better grammatical construction or more clear presentation of the matter treated of in the amendments, although I want to say for the Committee, and I think for all of those, especially those who are in the grade of Associate Member, that the Committee did not think that any such change as a change of Associate Member to Junior would be at all approved by the membership of that grade or perhaps by the other grades.

What is embodied in those amendments and also in the suggestion of the Minority Report is a revision of the grade of membership, which seems to have met with the unanimous approval, not only of the entire Committee, but of all those members who have spoken on this subject, and who have given any expression on the matter to the Committee.

It is perhaps fair to say that, in the discussion of this question, it should be recalled that the suggested changes in the Constitution that have affected those representatives of the grade of Member were transmitted by circular to all the membership of the Society; that each Corporate Member of the Society at least has had an opportunity to express himself on this question during the last six months; that any communication that might have been received by the Committee would have been considered; and that the Committee is now trying to present to you something which seems to them to be tangible.

Of course, I cannot speak for the entire Committee, but it seems to me that any verbal changes that would be in the nature of an

Discussion on Proposed Amendments (Continued).

improvement of the grammatical construction of the amendments should be embodied, and the Committee would gladly undertake such modifications of the suggested amendments if this Convention thinks the proposition embodied in the report should be recommitted to the Committee; although I want to say positively that I know, from the opinions of the several members of the Committee, particularly as expressed by Mr. Noble, Mr. Bates and Mr. Whinery, that a change in the nomenclature of the different grades would not be entertained, because it certainly would be confusing to use now for the Associate Membership grade the title of Junior, and it would be very unwise to institute such a radical change.

The one particular paragraph or amendment in which the Minority Report was perhaps especially interesting was that relating to Associates. It seems to me that the suggested change in that particular amendment would be rather unwise and would still further complicate the requirements by adding to the paragraph, instead of the part that is stricken out by this amendment, "although he may have reached the qualifications for Associate Member or for Member." That would still leave the paragraph somewhat ambiguous, and it seems to me that the requirements for the several grades should stand on their own footing.

THE PRESIDENT.—Any further discussion?

MR. TRAUTWINE.—Perhaps at this point, Mr. President, I had better refresh the recollection of the members present, and especially inform those who were not present at the meeting the other morning, as to just what the Minority Report means.

I think it is just as well that the suggestion which I made as a minority member of the Committee was not printed, as that report of mine was not made with the intention of being presented here as a Minority Report, but simply in response to a request from the Chairman of the Committee that the members of the Committee would send to him their criticisms of the Committee's proposed report. I found it most convenient to send my discussion in the form of a new reading. The Chairman informed me it was too late to act on that, and asked that it be handed in as a Minority Report. This I did, although I felt that it was a rather weak and vain document.

I should like to say that there is entire unanimity, as far as I know, between the remainder of the Committee and myself, especially in regard to what seemed to be the tendency of the amendments originally suggested, which seemed to wipe out the two higher grades of membership after years of practice, and seemed to substitute for it simply a high grade of professional attainments, upon which future Committees might take the most varying and different views. It seemed to me that there should be no letting down of the

bars, and that this requirement of professional high standing should be introduced, not as a substitute for that, but in addition to it.

All that I suggested in the way of amendments to the Committee's report was of a verbal character, and was intended to get the report and the Constitution into better and more harmonious shape. It seemed to me that this was a fine opportunity to do away with several ambiguities which have existed for many years, especially in the double meaning of the word member. For instance, a person well acquainted with the procedure of the Society, or its nomenclature, comes to me and says: "Trautwine, you are a member of the American Society of Civil Engineers?" And I say, "Yes;" and a friend of mine who has overheard the conversation comes to me and says: "Trautwine, you know you are lying, you are only an Associate." And I have to construct a diagram to show the meanings of the different terms.

In a word, we have this conflict of terms. I strove to get over that, and made a suggestion which now strikes me as rather fanciful, that those four grades which are now called Member, Associate Member, Associate and Junior should be called, respectively, Senior, Junior, Associate, and Student.

As Mr. Sherrerd has very well pointed out, the idea of substituting the word "Junior" for "Associate Member" is not to be seriously thought of; that the Associate Members could not be expected to vote for it, for one thing, and could not be expected to get a job if they announced themselves as Juniors.

I suppose it is still in order for me to act in the minority, and what I would suggest would be to call the first grade of membership the Senior Members, and make no other change in the nomenclature: Senior Member, Associate Member, Associate and Junior.

A less serious matter, which I mentioned the other day, was with respect to Naval and Military Engineering. It seems to me this is an error in nomenclature. The matter is not very serious, however.

The third matter—which does strike me as serious—was the reading of the section specifying the qualifications of a member as an Associate. The printed Constitution says, as nearly as I can remember it, an Associate shall be a person qualified to co-operate with engineers by reason of study and experience, but who is not himself a practical engineer. As I explained, the other morning, there was a time when my right to exist as an Associate was questioned. I had not then attained the qualifications necessary for the higher grade of membership, and I had designed a fence post or something of that kind, enough to have it said that I had done some engineering, and that I was therefore disqualified to act as an Associate.

It seems to me that it can hardly be right that a person who has

Discussion on Proposed Amendments (Continued).

given some attention to the science of Engineering should thereby be debarred from all membership in the Society, because he has done a little engineering work but not enough to qualify himself for the higher grades. The Committee advocated leaving out certain words, which would have left the clause rather ambiguous, because all that would have been left would have been the qualifications which the Associates should have. Therefore I suggested adding the words: "But who is not qualified for admission to the higher grades."

MR. COATES.—I would make a motion that this report be taken up by sections and a vote on the report be made by sections.

(Motion duly seconded.)

THE PRESIDENT.—It is moved and seconded that this report be taken up by sections and voted upon. This matter is open for remarks.

JAMES OWEN, M. AM. SOC. C. E.—Is it necessary to vote on these amendments unless they are amended?

THE PRESIDENT.—I think it is not.

MR. WILLIAMS.—Did I understand you to rule on the motion just made?

THE PRESIDENT.—They could be taken up for consideration by sections, and if it is not amended I think it is not necessary to vote upon them.

MR. CONDRON.—I think there is quite a feeling of uncertainty among a good many as to what this meeting is supposed to do with reference to this report. It was explained at the early meeting, but some have come in since, and an explanation would clear it up.

THE SECRETARY (Reading from Constitution):

"If, after discussion of a proposed amendment, at either of the general meetings of the Society, the meeting shall so decide by a majority vote, it may refer the amendment to a Committee for further consideration, which Committee shall report at the next general meeting"—that is the state that has been reached now—"whereupon the amendment shall be voted upon as hereinbefore provided."

Now, the "hereinbefore provided" is that, when brought before a Business Meeting of the Annual Convention, proposed amendments

"may be amended in any manner pertinent to the original amendments by a majority vote of the Business Meeting during the Annual Convention, and, if so amended, shall be voted upon by letter-ballot in form as amended by said Business Meeting; if not so amended, they shall be voted upon by letter-ballot as submitted."

MR. WILLIAMS.—In speaking on the last motion, I would like to suggest that it seems to me that the purpose of this meeting—the advantage of it—is to present such suggestions as the members may

have as to the modification of this language, and in the end this matter must be referred back to the Committee, or recommitted, expecting the Committee to modify the language so as to meet with the general sentiment of the meeting, and to send it out to the membership for further consideration. It hardly seems to me that it is necessary to take a vote on this by sections, and that it would require an undue amount of time to deal with that. I think the bulk of our corrections would be found in one paragraph here, and when that is done that will be all that is necessary.

THE PRESIDENT.—I think that motion is unnecessary, in view of the Constitution, clauses from which have been read, but the matter can be taken up for consideration by sections without any motion. The only consideration that is necessary is in the line of amendments or suggestions; and I would suggest that if any one has any suggestions to make in regard to the first section that they will make those suggestions so that we may follow along in an orderly manner, if that is what is suggested by the member.

MR. OWEN.—May I suggest that the Secretary read Section 1 for the benefit of the meeting, and if there is any suggestion in answer to that, it may then be taken up.

THE SECRETARY.—I have here the signed report of the Committee, which has come by mail since the last Business Meeting, and there may be some little differences between it and the report as printed, although I do not know that there are such differences:

"Strike out Sections 1, 2 and 3 of Article II, present Constitution, and substitute three sections, as follows:

"1. The Corporate Members of this Society shall be designated as Members and Associate Members. Corporate Members shall be Civil Engineers; the profession of Civil Engineering being here defined as including the branches commonly called Civil, Mechanical, Mining, Electrical, Military and Naval Engineering, and embracing Architecture and Naval Architecture. There may also be connected with the Society, Honorary Members, Associates, Juniors and Fellows, who shall be entitled to all the privileges of the Society except the right to vote and to hold office therein; provided that Honorary Members elected from the Corporate Members of the Society shall retain their right to vote and to hold office."

THE PRESIDENT.—The Section is now open for consideration.

C. C. SCHNEIDER, PAST-PRESIDENT, AM. SOC. C. E.—I would suggest changes in the second sentence, to read as follows: Corporate Members shall be Civil Engineers of all branches of the profession, and embracing Naval and Military Engineering and Naval Architecture.

(Motion duly seconded.)

THE PRESIDENT.—Was that made as a motion, an amendment or as a suggestion?

Discussion on Proposed Amendments (Continued).

MR. SCHNEIDER.—As a suggestion.

MR. WILLIAMS.—I am quite inclined to agree with the sentiment of Past-President Schneider's suggestion. It occurs to me, however, that the words "including all" should be "including any," because it might be interpreted to mean that a man must be all of those kinds instead of any one. It has occurred to me that the language of this section is somewhat ambiguous, owing to the statement that "Members shall be Civil Engineers," and then the Section proceeds to define Civil Engineering, but does not define Civil Engineers.

The definition of Civil Engineering is not particularly objected to, except that it seems to me that Mr. Schneider's is better, as being somewhat broader and leaving openings for future Engineers that may bob up. We have heard of "Sugar Engineers," and we talk of "Chemical Engineers" and some people talk of "Hydraulic Engineers," although I regret that anyone has seen fit to make a separate section of that branch of the profession.

It would seem desirable for the Committee to consider whether or not it may not be possible to use a little more general wording here that will take care of the future as well as the present.

Then there is further the question as to whether a man shall be a Civil Engineer, or whether he shall have been at some other time; that is to say, if a man must be a Civil Engineer at this time and shall thereafter retire from the profession, if he would thereby lose his Corporate Membership. That seems to strike me as being a point that the Committee has overlooked, and one that it seems to me should be considered in the wording of this Article. In fact, I think that the Article might be reworded almost from the beginning and gotten into a somewhat clearer shape than it is now, and it may be a question of whether a general definition of Civil Engineering, somewhat resembling the long accepted one of the British Institution, might not serve better. That was made to include Mechanical, Mining, Electrical, and so on, Engineers; and if such a definition be made I would say that it seems to me that in addition to Tredgold's definition we should include the word "science."

Let it read in general in this manner: Civil Engineering is the Art and Science of bringing the sources of power in nature to the use and convenience of man. In Tredgold's day, I think we might safely say, there was no Science of Engineering, but we have gradually been building up, and we have now a considerable Science of Engineering, and we should recognize that in any definition of the profession that is attempted at this date.

MR. BURDEN.—I am very heartily in accord with Mr. Schneider's suggestion, because it seems to me that this list which is given here is incomplete. It is already incomplete, and a year or two from now it will be still more so, because Engineering is becoming more and

more of a specialty all the time. Already it might be asked whether a Mining Engineer is any more or any less a Civil Engineer than a Railroad Engineer.

THE PRESIDENT.—Any further suggestions in regard to this Section?

MR. MARBURG.—Do I understand Mr. Schneider to exclude Architect?

MR. SCHNEIDER.—It was my intention to omit Architects, because, if we left the word "Architect," we would be compelled to admit, as a full Member, any one who calls himself Architect, and who has been in business for five years. Many of those who call themselves Architects, nowadays, are neither architects nor artists, but decorators.

MR. MILLER.—I believe I made that suggestion in the previous Business Meeting; for this reason, that Architecture is one of the fine arts, and Engineering is, as has been suggested, a science, and there are many architects who have reached eminence in their particular line, but who are not qualified as Engineers, and I think ought not to be admitted to any of the grades of membership. They should properly be placed in our grade of Associate.

THE PRESIDENT.—Any further suggestions?

J. A. OCKERSON, M. AM. SOC. C. E.—The gentlemen are laboring under a misapprehension in one respect. If we do not amend these sections, but merely make suggestions, they go out to letter-ballot. It seems to me that we want amendments unless the members see fit to retain them to the Committee. Suggestions don't fill the bill.

MR. BELL.—Following the remark made by the gentleman who has just spoken, it seems to me that the matter is not thoroughly understood by the Society, and as I happen to be practically an outsider, being a Canadian, it seems to me reasonable that it would be a good way to refer it back to the Committee and leave it to another year, until the matter is thoroughly understood. I merely throw that out as a suggestion.

EMIL SWENSSON, M. AM. SOC. C. E.—In answer to Mr. Ockerson's remark, I believe that it is the intention to have this recommitted to the Committee for further consideration, and these suggestions are for their benefit. It started yesterday morning—I believe Mr. Miller moved that it should be recommitted—but then it was the sense of the meeting to have a further discussion so as to give the Committee a few hints as to how they wanted it to be in shape finally.

MR. MILLER.—Then I understand that motion of mine to recommit is still before the meeting. It is duly seconded, I believe, and has never been voted on.

THE PRESIDENT.—It can be renewed to-night.

Discussion on Proposed Amendments (Continued).

MR. MILLER.—Is it necessary to make the motion to recommit now, or is not the motion still pending without action?

THE PRESIDENT.—I think it would be better to make a new motion.

MR. MILLER.—As I understand, the motion was practically laid on the table while this present section is now under discussion. If necessary, I will make the motion again—I do not remember the wording—there was some suggestion as to instructing the Secretary——

THE SECRETARY.—It is merely a motion to recommit the matter to the Committee to be reported at the next Annual Meeting. I think your motion was to refer the whole matter to the Committee to report at the next Annual Meeting.

MR. MILLER.—Yes.

MR. WILLIAMS.—If I might be allowed to refresh the memory of the Secretary on the point, I believe that one point included was that the Committee should send out a copy of its revised report preceding the Annual Meeting in order that the members might be familiar with the resolution at the time of the meeting.

THE SECRETARY.—I think it ought to be carefully included in the resolution.

MR. MILLER.—I thought that had been included.

MR. OCKERSON.—Why not go on with the consideration of the Section, and then if the gentleman wants to revise his motion to recommit he may do so. If we recommit now it would cut off all the suggestions.

THE PRESIDENT.—Will the gentleman postpone his motion to recommit until further consideration? Are there any further suggestions in regard to Section 1?

O. E. MOGENSEN, M. AM. SOC. C. E.—I have not heard any of the older members express themselves on Mr. Trautwine's suggestion, and I think that those who have passed through the different grades and have been Associates, have felt the same as Mr. Trautwine has felt, when they have been asked if they are members and have had to give long explanations. I think Mr. Trautwine's suggestion is important and to the point, that is, that the grades be known as Senior Member, Associate Member, Associate and Junior.

S. BENT RUSSELL, M. AM. SOC. C. E.—If the motion is in order, I would like to move that it is the sense of the meeting that architects should be placed among the Associates and not among the Corporate Members.

MR. WILLIAMS.—I will support that motion.

WILLIAM C. FURBER, M. AM. SOC. C. E.—I think the Civil Engineers' Society, the American Society of Civil Engineers are constantly narrowing themselves, so that instead of embracing the

whole circle of engineering, they are liable to be railroad engineers and bridge engineers and surveyors. If you look over the field of electrical engineering, you will find that the electrical roads are not being built by the Members of the Society; if you look over the mechanical structures being erected over the country I think you will find that there are many not being erected by members of the American Society of Civil Engineers. I do not think that any of the members who have spoken against including architects would do so if the members realized the extent and the value of the services that the architects perform.

The statement that they are decorators is not true of the great men of that profession. It is not true of the men who designed the monuments of antiquity, the magnets that draw travelers across the ocean. I think it would be a great mistake to exclude the architects from the professional members of the Society.

Mr. Trautwine.—It occurs to me that it would be unwise and improper to strike out Architecture as a branch of Civil Engineering, under the definition quoted here this evening. Engineering being the science and art of directing the great sources of power in nature to the use and convenience of man, Architecture is a branch of Civil Engineering. It is the art of decoration in Civil Engineering applied to the construction of buildings. It may very well happen that men who call themselves architects are only decorators of buildings or furnishers of designs for buildings; but it seems to me that that is not a proper excuse for leaving them out as a branch of Civil Engineering, and that it should be the province of the Membership Committee to say whether an architect has been engaged in responsible work or whether he is a mere decorator.

Mr. Seaman.—I think that if an architect practices in connection with his profession, Engineering, he is an Engineer, and as such should be admitted, but merely that he is an architect does not make him an Engineer; and I think that the architect should be excluded from the list of engineers unless he is an engineer himself. It has been said before our Society that the Architect is the Engineer of the world. I think it may be more rightly said to-day that the Engineer is the Architect of the world.

J. Waldo Smith, M. Am. Soc. C. E.—It seems to me that this matter of architects and naval engineers is taken care of by the present Constitution. An architect applies for membership and if he has all the qualifications of a member he is placed in the grade of Member. If he has the qualifications of the Associate he is placed in that grade; and I do not see why the matter is not all right just as it stands.

Mr. Swensson.—I most heartily agree with Mr. Smith. I think the name "architect" should not be stricken from the classified mem-

Discussion on Proposed Amendments (Continued).

bership, but that the Board of Direction through its Membership Committee will take care of the matter of classification and put the man where he belongs.

THE PRESIDENT.—Any further discussion of Mr. Russell's motion?

MR. RUSSELL.—It seems to me that these amendments—these Articles as amended here—do not read as being very complete. We embrace Architecture and Naval Architecture when we say that a Member must have been practicing Civil Engineering. Now, it does not seem to me that it follows, because a man is an architect, that he would have been practicing Civil Engineering. The architect does not necessarily come within the definition of Civil Engineering, I should think.

THE PRESIDENT.—Is there not a definition given here as to what Civil Engineering means in this particular case?

MR. RUSSELL.—In the section just referred to?

THE PRESIDENT.—Yes, in Section 1.

MR. RUSSELL.—I overlooked that.

THE PRESIDENT.—What was the motion?

MR. RUSSELL.—My motion was that architects be included——

THE PRESIDENT.—That it is the sense of this meeting——

MR. RUSSELL.—I move that it is the sense of this meeting that architects should be placed among the Associates and not among the Corporate Members. As near as I can remember, that was the wording of it.

THE PRESIDENT.—Something to the effect that it was the sense of the meeting that Architecture and Naval Architecture should not be excluded in the first section?

MR. RUSSELL.—I think I used the word "architects" in my original motion. I do not think I used the word "architecture." I was referring more to persons than to the wording of the section. They should be admitted to the Society as Associates and not as Corporate Members.

MR. WILLIAMS.—I move to lay this motion on the table.

(Motion seconded.)

THE PRESIDENT.—It is moved that the motion of Mr. Russell be laid upon the table. These who are in favor of the motion will say "aye"; those opposed, "no."

The motion is carried.

R. L. HUMPHREY, M. AM. SOC. C. E.—Is the motion by Mr. Miller, to refer these amendments to the Committee, on the table? What became of that motion?

THE PRESIDENT.—It was deferred; it has not yet been submitted. If there is nothing further to be said in regard to Section 1, we will proceed to the consideration of Section 2. I will ask the Secretary to read the section.

THE SECRETARY. (Reading):

"2. A Member shall be, at the date of his admission, not less than thirty-three years of age, shall have been in the active practice of Civil Engineering for not less than ten years; shall have had responsible charge of engineering work of importance and merit for at least five years, and shall be qualified both to design and to direct engineering works. He shall also have attained a recognized position of honorable high standing in the profession. Graduation from a school of engineering of good standing shall be considered as equivalent to two years of active practice. The performance of the duties of professor in any of the branches of Civil Engineering in a technical school of high grade shall be considered as equivalent to an equal number of years of active practice."

J. A. POWERS, M. AM. SOC. C. E.—I must make objection to the new part of this section which reads: "He shall also have attained a recognized position of honorable high standing in the profession." It seems to me that there is no person here present who does not know that it is not at all uncommon, in fact, rather common practice in Engineering, in a work of large magnitude or even of moderate magnitude, to employ at the head of the work one who may possess these qualifications, but to employ as an associate, or rather as a second engineer in the work, a man who does the real work and who is the engineer, as we understand it, and who has the qualifications for membership in this Society.

Now, it seems to me that, in this country, we are coming to a point where there is altogether too much recognition of position, and too little recognition of what this Society stands for, Engineering work of real merit. I do not think that this Society should take any position that will prefer the high-stepper to the wheel-horse. It seems to me that the standard that we have set up without this qualification is ample to guard against the admission of improper persons by this Society, if the rules are enforced by the Committee, according to the rules of the Constitution. I do not think that it is any part of the duty or the requirements of the Society that it should take the position of aiding in putting this stop on one of the old-fashioned American virtues of modesty, and I do not believe that this portion of the section should be added to the Constitution.

THE PRESIDENT.—Any further suggestions in regard to Section 2?

EMIL KUICHLING, M. AM. SOC. C. E.—In connection with Section 2, the definition adopted in Section 1 is to apply. There were here some objections to and arguments in favor of the qualification of architects as Corporate Members. Section 1 provides that the profession of Civil Engineering includes and embraces the profession of Architecture and Naval Architecture. Now, a professor of Naval

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Architecture or Architecture in any School of Engineering in good standing becomes eligible as a Corporate Member, according to this, or any Architect or Naval Architect is eligible as a Corporate Member. I merely take that question up as depending upon the definition adopted as to what we mean by the term Civil Engineer.

THE PRESIDENT.—Any further suggestion in regard to the section?

MR. TRAUTWINE.—In regard to the gentleman who spoke to the point of the insertion by the Committee of the words "honorable high standing," I might say in behalf of the Committee that I think there is no intention of meaning gilt-edged, high standing, but simply that the man should be recognized as having attained a standing such as should entitle him to membership, and such as Members and Associate Members possess at the present time. The motive of the Committee in inserting this as part of the original motion was this: As I understand it, under the provision as printed, where a man should have had charge of engineering work for a certain number of years, etc., it might be possible to admit wheel-horses and very excellent applicants would not be eligible to membership in the Society. They might be men calculated to figure out calculations, or to handle a pick, etc. The idea was that they were to have in view the necessity of some degree of engineering skill and ability. Possibly the Committee has not been wise in the choice of words, and if that is to be the result of the use of those words—that we want none but men entitled to wear medals—it would seem that our choice of language was not a good one; but it seemed to the Committee well to give some hint to the members that a little more than mere ability as a draftsman is necessary.

MR. POWERS.—If any sin was committed, it was, in my mind, one of omission, but I did not mean to charge them with any sin. I merely wanted to state my personal opposition to the recognition of positions that are created for social or political consideration as compared with those filled by the men who do the real work. I know of some who have created some of the greatest engineering works in this country who would certainly not come under this qualification if it was strictly interpreted, and yet there are no men in this world more entitled to membership than they are.

I had not intended to be one of those who, as Mark Twain says, are willing to criticise the German language but are not willing to take proper means for its correction. I meant to add to my remarks that there should be stricken from Section 2 the words which I read.

MR. OCKERSON.—On account of these words which require that a man should be competent to practice engineering, the Chief of Engineers of our Department has made a rule that a man cannot become employed as a Civil Engineer unless he is eligible to mem-

bership in the American Society of Civil Engineers. We have a number of men who do geodetic work of a high grade. They do not do engineering work at all. The American Society of Civil Engineers says they are not eligible, and they are in a pretty bad fix. I should be very glad if it could be modified to include such men as work in the geodetic survey and in our work on the Mississippi River.

MR. SHERRERD.—I got up to speak on Mr. Powers' suggestion, but I would like to answer the previous speaker by saying that it does not seem to me that the Society ought to change its Constitution in order to fit in with the rules of some Government department. The question about the wording as to attainments for membership calls for a recognized position of honorable high standing. I would like to say on behalf of the Committee that this question was considered at great length, and while personally I prefer the wording to be, "he shall also have attained a recognized position of high standing in the profession," it is suggested that there are some members of the profession who have attained high standing which is not especially creditable; and it might be safer to put in the words "honorable high standing." The words are used here in that sense, to disqualify the man who has attained a discreditable position of high standing.

MR. MARBURG.—I would like to suggest the desirability of making the requirements as specific as possible. Those of us who find it necessary to pass in review members for positions as graduates, scanning the positions and seeking to scan without bias and in favor of the candidate, to whom they are naturally favorably disposed, would find this unnecessary, it seems to me; and it leaves the words open to different constructions by different individuals. The individual will find himself face to face—after he sees that the candidate has met with the specific requirements—with this difficulty, that he is called to decide as to whether he has obtained a position of honorable high standing. If a man meets the requirements stated without this clause which Mr. Powers moves to eliminate, it seems to me he must of necessity have attained to a rank that the Committee designates somewhat vaguely as one of honorable high distinction.

THE PRESIDENT.—Any further suggestion in regard to this section?

MR. WILLIAMS.—In order to get the matter into the record, I would say that in the first line of this paragraph, after the word "admission," the words "to that grade" should be inserted. I think that the member should be at the date of his admission to that grade not less than thirty-three years of age; and in the last line the words "an equal number of years" should be stricken out, to make

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the proper logical sense; so that "the performance of the duties of a professor of engineering in a technical school of high grade shall be considered as equivalent to an equal number of years of active practice," instead of being equal to a number of years of the performance of duties—which is the point raised by Mr. Trautwine, and I think is very well taken.

A. T. Throop, Assoc. M. Am. Soc. C. E.—I would like to make a suggestion that in the sense that he shall also have attained a recognized position of honorable high standing that the word "recognized" be omitted, and it shall read that "he shall also have attained a position of honorable high standing in the profession," and let the Board of Direction recognize that honorable high standing by admitting him to membership.

Mr. Marburg.—Did Mr. Powers make a motion to eliminate that?

Andrews Allen, M. Am. Soc. C. E.—I object principally on the ground that it substitutes an opinion for a fact. Recognized position is simply the general recognition of others, or else it means nothing at all. I would very much prefer to see the requirement simply one of professional attainments as expressed by the work a man has done, whether the world recognized it or not. I would like to have a vote on Mr. Powers' motion.

Mr. Sherrerd.—In regard to that, this same word was also considered carefully by the Committee and used. It was intended that the same method of obtaining information regarding candidates should be proceeded under, in this suggested amendment, as is now proceeded under, as to whether a man has had responsible charge of work. The circular letters that we send out would inform the Board of Direction as to whether the candidate had obtained a recognized position. That recognized position would be one which would be the recognition of the fellow members of the Society, from whom the Board of Direction had received answers to the circular letter, or from whom they might have received information in regard to the candidate—not the general recognition of the public, but the recognition of the membership.

W. D. Pickett, M. Am. Soc. C. E.—Is there a motion before the meeting?

The President.—I do not understand that there is a motion before the meeting.

Mr. Powers.—I will try to follow the example of the illustrious Mark Twain, when he tried to improve the German language, by saying that after he had studied it for six weeks he resolved to turn the job over to somebody else—I will make a motion that the words "he shall also have attained a recognized position of honorable high standing in the profession" be stricken out of Section 2.

A MEMBER.—We cannot strike that out.

THE PRESIDENT.—It would be necessary that it should be the sense of the meeting, and so I understand that you have made it that way.

MR. POWERS.—Correct.

THE PRESIDENT.—That it is the sense of the meeting that the words "he shall also have attained a recognized position of honorable high standing in the profession" be stricken out. That motion is made and seconded, and Mr. Owen has the floor.

MR. OWEN.—I ask if it is the proposition that there should not be any restriction of membership except the actual engineering qualifications? It seems to me that one of the functions of this Society is not only the engineering qualifications but the moral qualifications attached to it. It seems to me that that should be cared for. It has been recognized heretofore, and it has been recognized by the proposed amendment, but it would be totally abolished by this suggestion.

MR. KNAP.—It seems to me that we are simply following this line, to make suggestions, and we are not to pass any motions amending the Constitution—although the Constitution is all right among friends—but we must pay some attention to those who are not here, and I therefore think that anything that is done now should be in the shape of suggestions and not motions, so as not to get the matter confused. The sense of the meeting might be considered as passing a resolution amending this report; and I understand we are not doing that, but are simply taking up these sections to call for suggestions from the different members, the sense of the meeting to be considered by the Committee.

THE PRESIDENT.—The meeting may, if it wishes, take the sense of the meeting, so that the Committee may have it before it. They cannot make a motion to change the Constitution unless they wish to prepare it for going to ballot.

MR. CONDRON.—It seems to me that the sentiment here is that it is so ambiguous to this company, that that is indicative of the fact that it would be equally ambiguous to various Membership Committees in the future. While the present Membership Committee understands what they mean and what they have in mind, and what they intend to do, there may be other Membership Committees in the course of even a very few years who will not have such a clear idea of what is intended; and this sentiment, if it is embodied in the Constitution at any time, might lead to very gross misuse of the power that would be put in the hands of a Membership Committee, by excluding from membership in the Society excellent engineers, simply because they did not belong to a particular clique which had attained to the degree of eminence which that Membership Commit-

Discussion on Proposed Amendments (Continued).

tee considered was necessary. In other words, for example, no engineer might be sufficiently high and honorable in standing unless he lived in a particular ward in New York City. I think that it is a very important point, and I believe, from the remarks which I have heard all around, that a good many feel that these are dangerous sentiments to put in this particular form, and I will most heartily support Mr. Powers' motion.

G. E. GIFFORD, M. AM. SOC. C. E.—It seems to me that some of the members have a wrong idea of the Membership Committee. I understand that the Membership Committee is the Society. The membership, I think, does not mean the Board of Direction, who simply rule whether the thing shall go to ballot at all, and that is all they do in the way of membership.

THE PRESIDENT.—I am going to ask the Secretary if he will say something on this point, because I think that the Members of the Membership Committee have found that something was necessary in order to exclude some people who should not be in the Society. I think the Secretary can explain the situation, as he is familiar with it. I think the wording of this particular clause may not be satisfactory.

THE SECRETARY.—Mr. President, in regard to the question of putting more power in the hands of the Board of Direction, I do not believe that this, in whatever shape it is passed, would add any more power to the Board of Direction than it now possesses. The Board can now prevent any candidate from going to ballot at any time. When a man has had the requisite number of years' practice and has all the other qualifications, and requests for information go out, six or seven answers from members of the Society are generally received, and in some cases when these answers are analyzed they show that he is eligible for each and every grade in the Society, and it is difficult for the Board of Direction to decide as to his proper grade.

If some such additional qualification—I am not speaking of the language of this particular clause—if some additional qualification were made by which the Board of Direction could say to a candidate, "It is true that you have had the required number of years in active practice and that you have been in responsible charge of work for the specified time, but the Board does not think that you are quite up to the grade of Member," it would be more satisfactory both to the Board and to the candidate.

MR. RIGGS.—I would like to ask if the Board of Direction, in determining the classification, does not do exactly what Mr. Hunt says? Don't they take into consideration all these facts; don't they put the Member where he belongs?

THE SECRETARY.—I think they do as far as they can, but if the

Board now considers the character of the work as well as the amount, it must take a somewhat arbitrary position not warranted by the letter of the Constitution.

MR. RIGGS.—I am convinced that the Board ought not to have further authority in that matter; I believe that they have enough. I believe that they have exercised it. I believe that the whole matter should be left to them without compromising ourselves on such a statement. I am heartily in favor of having it stricken out.

MR. GOLDMARK.—I think the fear of making this grade of Member dependent upon a standing that may be simply a popular one rather than based on real professional merit is nothing that we need be very much afraid of; but I do think that it is desirable for the Society, it is desirable for the younger members who intend to become and hope to become full Members, that the standard should be as high as possible; and I think that any clause or any direction given to the Board by the Society to raise that standing, to make "Member" mean as much as it possibly can is a step in the right direction.

I have never been on the inside of this question, and know nothing about it except as an observer of the men who are elected. Now, in a Society scattered all over the country, it is only just to those who happen to be acquainted in their special localities, who can judge best perhaps as to whether they should be Members, Associate Members or Associates. I must confess that I have been struck again and again with the men who have been elected as Members of the Society, who, in my opinion, had not really reached a degree of maturity or a degree of eminence and skill in the profession which would warrant their being elected as Members; and I think that a raising of the grade would be very desirable. I think that a clause to that effect, perhaps not exactly with that wording, would be healthful rather than harmful, and would make it more of an honor, more of an advantage to be called a Member than if merely a number of years is laid down as a standard, as in many cases, particularly with those who take an interest in the Society, and make a point of getting into the Society at the very earliest date at which under the letter and rule of the law they can get in. I have felt particularly chagrined as I have watched elections for ten or fifteen years and have seen a good many men get in as Members who were really not as fully qualified as they should be.

C. F. LOWETH, M. AM. SOC. C. E.—I am in favor of retaining the clause, except that I think we might modify it by striking out the word "recognized" as has been suggested. I would move to amend the motion that we are now discussing so as to omit the word "recognized."

MR. ALLEN.—I second the motion.

Discussion on Proposed Amendments (Continued).

THE CHAIRMAN.—Are you speaking now to the amendment?

MR. ALLEN.—Yes. If the whole membership of the Society vote on an application with the clause as proposed here, or even with the modified clause as suggested by Mr. Loweth, I believe that if we vote conscientiously upon a straight interpretation of that clause and with the usual percentage of personal knowledge that we have, I believe that eighty per cent. of the applicants for Membership would be blackballed. The people who have honorable high standing in the profession are few and far between.

MR. WILLIAMS.—It seems to me that this is a matter that this meeting is not required to agree upon. I think that the Committee has received ample light upon the sentiment of the Society, and I think we can trust them to overhaul this clause and get it into a shape that will meet the views of most of us.

I think there is none here who wants to stand in the way of raising the membership. There is no member who would exclude the Board of Direction from considering a man's moral character and deciding whether he should be a Member or not, and I therefore move to lay the motion on the table.

(Motion duly seconded.)

THE PRESIDENT.—It is moved that both the first motion and the amendment to that motion be laid upon the table. Those in favor of the motion will say "aye"; those opposed, "no." Those in favor of laying this motion on the table will raise their right hands.

THE SECRETARY.—Sixty-seven.

THE PRESIDENT.—Those opposed, the same sign.

THE SECRETARY.—Twenty.

THE PRESIDENT.—The motion is duly carried.

MR. WENDT.—I propose a motion that it is the sense of this meeting that all debate should now cease and that the entire report of this Committee should be referred back to it with instructions to prepare a new draft for submission at the next Annual Meeting.

MR. PICKETT.—It is a matter of very great importance to the Society, and it should not be decided hastily. We have a membership of 2 500 voting members, I believe, Corporate Members?

THE SECRETARY.—Yes, sir, 3 000.

MR. PICKETT.—There are present now maybe 125 or 150, one-twentieth of the voting members of the Society. I think this whole matter ought to be referred to a letter-ballot, and, if I am in order, I move that the report of the Committee be received and that each section, section by section, shall be submitted to a letter-ballot, and I hope that the report of the minority as well as of the majority will be distributed.

MR. WILLIAMS.—I rise to a point of order. The suggestion is——

THE PRESIDENT.—A motion has been made that the report be referred back to the next Annual Meeting. That is the course that has to be followed.

MR. WENDT.—I modify that motion, and move that it be referred back to the Committee with instructions to prepare a new draft, and that new draft shall be printed a reasonable time before the next Annual Meeting in order that the Membership shall be fully advised as to what the nature of the report shall be.

THE PRESIDENT.—I was waiting for the discussion to finish; I was expecting that there would be some discussion on some of the other clauses. The gentleman who made the last motion I think should not be recognized for that purpose, because Mr. Miller had stated that he wished to make that previously and had deferred the motion.

MR. WENDT.—Let Mr. Miller make the motion.

THE PRESIDENT.—Yes, to that effect.

MR. MILLER.—I think, Mr. President, it would be well to get the sense of the meeting as to whether or not they wish to discuss the other clauses. If they intend to close the discussion why then this would come——

MR. HUMPHREY.—I move that the discussion be closed.

MR. PICKETT.—Is there a motion to refer the clause back to the Committee—I do not hear very distinctly?

THE PRESIDENT.—There was a motion that the debate be closed.

MR. WENDT.—I modify the motion by moving that it is the sense of the meeting that all discussion should now cease. I made that because I thought the remarks heretofore made applied as much to Section 2 as to Section 3.

(Motion duly seconded.)

THE PRESIDENT.—The motion has been made and seconded that the debate be now closed.

MR. RIGGS.—I should like at least that Section 5 as it now stands should be read. I do not know why we should stop. If these gentlemen are through, they can go, but I should like to stay and have this out.

THE PRESIDENT.—Those in favor of the motion will say "aye"; those opposed, "no." Those in favor of the motion will raise their right hands until counted, on the motion to close the debate.

THE SECRETARY.—Forty-eight.

THE PRESIDENT.—Those opposed will raise their right hands.

THE SECRETARY.—Thirty-nine.

THE PRESIDENT.—The motion is carried.

MR. MILLER.—I move that the proposed amendments be referred back to the Committee for further consideration and report at the next Annual Meeting, with instructions to send to the membership

Discussion on Proposed Amendments (Continued).

copies of all proposed changes, calling especial attention to the same.

(Motion seconded.)

THE PRESIDENT.—The Secretary will read the motion.

THE SECRETARY.—It is moved that the proposed amendments be referred back to the Committee for further consideration and report at the next Annual Meeting, with instructions to send to the membership copies of all proposed changes, calling especial attention to the same.

I would suggest that the motion be so amended that the report of the Committee be placed in the hands of the Secretary at least sixty days prior to the Annual Meeting so that he may be able to send it out in time.

MR. MILLER.—I accept the amendment.

THE PRESIDENT.—You have heard the motion, which is a motion to recommit. Those in favor will say "aye"; those opposed, "no." It is recommitted.

Letter from Mr. J. G. Spielman.

THE SECRETARY.—I have a letter here from Mr. J. G. Spielman, Associate Member, addressed to the Society, just received.

"CHICAGO, June 23, 1906.

"*American Society of Civil Engineers,*
"CHARLES WARREN HUNT, *Secy.*,
"Frontenac, N. Y.

"GENTLEMEN:—Believing that there is no better field for missionary work for this Society than in the building departments of our various cities, I take this opportunity of suggesting that a committee be appointed to investigate the building laws and regulations of our larger cities and to compile a set of regulations that will apply to all cities of the first class. Similar regulations could also be suggested for cities, say, of the 2nd and 3rd class. The important question now, however, is to frame a set of regulations which the Society with her standing and prestige could urge upon the various municipalities throughout the country.

"Some of the regulations now in force in some cities are no doubt wise and proper. There are, however, no doubt in the ordinances of every city, some foolish and ambiguous paragraphs. Some of our larger cities are considering the necessity for revising their ordinances, and I believe if the Society could lay before them a complete set of laws they would gladly adopt them.

"In the case of one city, they have failed to enact new laws for the reason that they have not the engineering and technical organization necessary to compile such laws. Their present force is overworked and tied up by red tape and political affiliations to such an extent that it is next to impossible to get satisfactory work accomplished.

"One set of laws for all cities of the same class would simplify the work of the engineer and architect. This, of course, would take time and work, but, I believe, not as much time or as much work

as less important questions which the Society has taken up and solved successfully.

"For the purpose of bringing the idea before the Society, I enclose a motion which you are at liberty to use as may seem best.

"Yours truly,

"J. G. SPIELMAN,

"Associate Member, Am. Soc. C. E."

THE SECRETARY (Reading):

"I move that the Chair appoint a Standing Committee of nine to investigate the building ordinances and regulations of our larger cities and report general ordinances and regulations applicable to such cities." Resolution by Mr. J. G. Spielman.

MR. WILLIAMS.—I move that we adjourn.

(Motion duly seconded and carried unanimously.)

Adjourned.

## EXCURSIONS AND ENTERTAINMENTS DURING THE THIRTY-EIGHTH ANNUAL CONVENTION.

The arrangements for the Convention were in the hands of the following Committee of the Board of Direction:

CHARLES S. GOWEN, *Chairman.*

JOHN W. ELLIS, MORRIS R. SHERRERD,

J. WALDO SMITH, CHAS. WARREN HUNT.

The convention rate of one fare and one-third, on the certificate plan, was granted to members and their families by the Trunk Line, Central, New England and Western Passenger Associations.

The meetings were held in the Hotel Frontenac, situated on Round Island, in the St. Lawrence River, near Clayton, N. Y. The island, about 200 acres in area, has a 9-hole golf course, about 2 600 yd. long, and during the Convention a Golf Tournament was held, in which members and guests participated and for which a number of prizes, paid for by special subscription, were presented.

On Wednesday, all in attendance at the Convention went on an excursion starting from Frontenac at 11.30 A. M., on the steamer *St. Lawrence* and proceeding to Gananoque, Ontario, where Mr. and Mrs. Charles Macdonald entertained the party at luncheon. The trip was then continued down the Canadian Channel to Alexandria Bay and up the American Channel to Frontenac, arriving at 6 P. M.

The boating and fishing in the neighborhood were very much enjoyed.

There was music and informal dancing every evening, and on Friday evening there was a reception and ball.

## THE ATTENDANCE AT THE THIRTY-EIGHTH ANNUAL CONVENTION.

The following 181 members were in attendance:

Ackerman, J. W..Auburn, N. Y.
Allen, Andrews....Chicago, Ill.
Allen, Henry C.Syracuse, N. Y.
Alvord, John W..Chicago, Ill.
Atkinson, J. B..Earlington, Ky.
Atwood, J. A....Pittsburg, Pa.

Babcock, W. S..New York City
Bacon, John W.Danbury, Conn.
Baker, H. E..Watertown, N. Y.
Ball, Charles B....Chicago, Ill.
Barnsley, G. T...Pittsburg, Pa.
Beardsley, J. W.Cortland, N. Y.
Bell, Andrew,
Ottawa, Ont., Canada
Betts, E. E.Chattanooga, Tenn.
Bond, Edward A..Albany, N. Y.
Bond, George W., Jr.,
Weehawken, N. J.
Bontecou, Daniel,
Kansas City, Mo.
Boucher, W. J..New York City
Brackenridge, J. C.,
New York City
Brackenridge, W. A.,
Niagara Falls, N. Y.
Brackett, Dexter..Boston, Mass.
Brady, S. D.,
Parkersburg, W. Va.
Brenneke, W. G.St. Louis, Mo.
Brooks, Fred.....Boston, Mass.
Brown, W. P...New York City
Burden, James....Troy, N. Y.
Burpee, Moses....Houlton, Me.

Carter, W. J...Cleveland, Ohio
Chapleau, S. J.,
Ottawa, Ont., Canada
Childs, O. W....St. Louis, Mo.
Churchill, C. S...Roanoke, Va.
Coates, F. R.....Chicago, Ill.
Coffin, Freeman C.Boston, Mass.
Conard, W. R.Burlington, N. J.
Condron, T. L....Chicago, Ill.
Connor, E. H.,
Leavenworth, Kans.
Cosby, Spencer,
Washington, D. C.
Craven, Alfred..New York City
Cummings, R. A.Pittsburg, Pa.

Davis, Charles...Pittsburg, Pa.
Deyo, S. L. F..New York City
Dorrance, W. T..New York City
Douglas, B.....Detroit, Mich.
Dufour, F. O.....Urbana, Ill.
Dyer, A. J....Nashville, Tenn.

Eddy, H. P....Worcester, Mass.
Edwards, J. H..Oxford, N. Y.
Ellis, John W.Woonsocket, R. I.
Ellsworth, E. A.Holyoke, Mass.

Fisher E. A..Rochester, N. Y.
FitzGerald, Desmond,
Brookline, Mass.
Flad, Edward....St. Louis, Mo.
Freeman, John R.,
Providence, R. I.
Fuller, W. B....Pittsburg, Pa.
Furber, W. C.Philadelphia, Pa.

Gahagan, W. H.Brooklyn, N. Y.
Gardner, W. M.Memphis, Tenn.
Garrett, J. T....St. Louis, Mo.
Gartensteig, C..New York City
Gifford, G. E..New York City
Goad, Charles E.,
Toronto, Ont., Canada.
Goldmark, Henry,
Montreal, Que., Canada.
Gowen, C. S....Ossining, N. Y.

Green, B. L....Cleveland, Ohio
Green, B. R..Washington, D. C.
Gregory, J. H..Columbus, Ohio
Grimes, E. L.....Troy, N. Y.
Grimm, C. R..Brooklyn, N. Y.

Hammond, A. J....Chicago, Ill.
Harrison, C. L..New York City
Haskins, W. J..New York City
Haven, W. A....Buffalo, N. Y.
Hazen, Allen...New York City
Hider, Arthur..Greenville, Miss.
Himes, A. J...Cleveland, Ohio
Hinds, F. A..Watertown, N. Y.
Hodgdon, F. W..Boston, Mass.
Horton, Horace E.Chicago, Ill.
Hughes, W. M....Chicago, Ill.
Humphrey, R. L.,
Philadelphia, Pa.
Hunt, Charles Warren,
New York City
Huntington, G. D.,
Watertown, N. Y.
Hyatt, C.,
Niagara Falls, Ont., Canada

Johnson, W. S....Boston, Mass.
Johnson, Wallace C.,
Niagara Falls, N. Y.
Kimball, G. A....Boston, Mass.
King, C. C.,
West New Brighton, N. Y.
King, Wallace, Jr.,
New York City
Kittredge, G. W.,
New York City
Knap, J. M....Catskill, N. Y.
Knowles, M.....Pittsburg, Pa.
Kuichling, E...New York City

Landreth, Olin H.,
Schenectady, N. Y.
Landreth, W. B..Albany, N. Y.
Leather, B. H..New York City
Leisen, T. A..Wilmington, Del.
Letson, T. A....New York City
Llewellyn, Frank J.Chicago, Ill.
Loweth, C. F.....Chicago, Ill.
Lyons, James K.Sewickley, Pa.

Macdonald, Charles,
New York City
McComb, C. O..Syracuse, N. Y.
McComb, D. E.,
Washington, D. C.
McKenzie, T. H.,
Southington, Conn.
McMinn, T. J..New York City.
Maignen, J. P. A.,
Philadelphia, Pa.
Marburg, Edgar,
Philadelphia, Pa.
Marvin, F. O..Lawrence, Kans.
Matcham, C. A..Allentown, Pa.
Maxwell, James R.Newark, Del.
Mercer, Charles H.Steelton, Pa.
Merrill, R. H....Fonda, N. Y.
Metcalf, Leonard..Boston, Mass.
Miller, R. P....New York City
Mills, C. M..Philadelphia, Pa.
Mogensen, O. E.,
Glens Falls, N. Y.
Moulton, Mace..New York City

Neilson, G. H....Braeburn, Pa.
Nethercut, Edgar S.Chicago, Ill.

Ockerson, J. A..St. Louis, Mo.
Opdycke, H. G..New York City
Opdyke, S. B., Jr.New York City
O'Rourke, J. F..New York City
Osborn, F. C...Cleveland, Ohio
Owen, James..Montclair, N. J.
Owen, K. D....Montclair, N. J.

Pegram, G. H..New York City
Phillips, R. H..St. Louis, Mo.
Pickett, W. D..Lexington, Ky.
Pill, John R.Carbon Hill, Ala.
Polk, W. A....New York City

Potts, Clyde....New York City
Powers, J. A.....Troy, N. Y.
Pratt, W. A....New York City
Proctor, R. F..New York City

Richardson, T. F.,
Clinton, Mass.
Ricker, George A.Buffalo, N. Y.
Riggs, M. J.....Toledo, Ohio
Rowe, Samuel M..Chicago, Ill.
Russell, S. Bent..St. Louis, Mo.

Schenk, C. L. E..Pittsburg, Pa.
Schneider, C. C.,
Philadelphia, Pa.
Scott, A. M..Charleston, W. Va.
Seaman, H. B..New York City
Selby, O. E..Cincinnati, Ohio.
Sherrerd, M. R..Newark, N. J.
Skinner, J. F..Rochester, N. Y.
Smith, C. E....Ossining, N. Y.
Smith, Edgar M..Chicago, Ill.
Smith, J. Waldo,
New York City
Smith, T. Guilford,
Buffalo, N. Y.
Spear, W. E..Providence, R. I.
Stearns, F. P....Boston, Mass.
Swensson, Emil..Pittsburg, Pa.

Talbot, A. N.....Urbana, Ill.
Thackray, G. E..Johnstown, Pa.
Thompson, Sanford E.,
Newton Highlands, Mass.
Thorn, Alfred W.Buffalo, N. Y.
Throop, A. T.,
Niagara Falls, N. Y.
Todd, A. M....Vicksburg, Miss.
Toensfeldt, H. C..St. Louis, Mo.
Tollinger, E. C.Vicksburg, Miss.
Trautwine, John C., Jr.,
Philadelphia, Pa.
Triest, W. G....New York City

Van Hoesen, E. F.Albany, N. Y.
Van Suetendael, A. O.,
Yonkers, N. Y.
Verveer, E. L..New York City

Wagner, J. C..Philadelphia, Pa.
Warder, J. H.....Chicago, Ill.
Webster, George S.,
Philadelphia, Pa.
Wendt, Edwin F..Pittsburg, Pa.
West, Oscar J....Chicago, Ill.
Whipple, G. C..New York City
Whiskeman, J. P.,
New York City
Whitford, N. E..Albany, N. Y.
Whittemore, W. F.,
Hoboken, N. J.
Wilcock, F....Brooklyn, N. Y.
Williams, G. S.,
Ann Arbor, Mich.
Willis, P.....Chicago, Ill.
Worcester, J. R..Boston, Mass.

Zeller, A. H....St. Louis, Mo.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, September 5th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "Concerning the Investigation of Overloaded Bridges," by Wilbur J. Watson, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in *Proceedings* for April, 1906.

**Wednesday, September 19th, 1906.**—8.30 P. M.—At this meeting two papers will be presented for discussion, as follows: "Street Traffic in New York City, 1885 and 1904," by Clifford Richardson, Assoc. Am. Soc. C. E.; and "The Ventilation of Tunnels," by Charles S. Churchill, M. Am. Soc. C. E.

Mr. Richardson's paper was printed in *Proceedings* for May, 1906; Mr. Churchill's paper is printed in this number of *Proceedings.*

**Wednesday, October 3d, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Narragansett Bay Coal Depot," by Augustus Smith, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

**Wednesday, October 17th, 1906.**—8.30 P. M.—At this meeting a paper, entitled "Fountain Flow of Water," by Messrs. F. E. Lawrence and P. L. Braunworth, will be presented for discussion.

This paper is printed in this number of *Proceedings.*

## PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 410 Penn Avenue, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner, Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten- Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesbrough, England.

**Civil Engineers' Society of St. Paul,** St. Paul, Minn.

**Koninklijk Instituut van Ingenieurs,** The Hague, The Netherlands.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

## LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

### San Francisco, Cal.

**May 5th, 1906.**—A special meeting of the San Francisco Association of Members, Am. Soc. C. E., was held; C. D. Marx in the chair; F. Riffle, Secretary.

Progress reports were received from the special committees on Geology; Revision of Streets; Sewers; Electricity, Lighting and Transportation; Water Supply; and Building Construction.

Suggestions were received from President Duryea in relation to the appointment of additional members on the special committees, and as to the work of such committees.

**May 19th, 1906.**—A special meeting of the San Francisco Association of Members, Am. Soc. C. E., was held in conjunction with the Technical Society of the Pacific Coast; A. L. Adams in the chair; F. Riffle, Secretary; and present, also, 9 members.

Progress reports from the following special committees were received and discussed: Geology of the Earthquake; Building Construction; Revision of Streets; Sewers; and Water Supply.

# ACCESSIONS TO THE LIBRARY.

From May 8th to August 4th, 1906.

## DONATIONS.*

### TYPES AND DETAILS OF BRIDGE CONSTRUCTION.

Part II, Plate Girders; Examples of Constructed Railroad and Highway Spans. By Frank W. Skinner, M. Am. Soc. C. E. Cloth, 10 x 6 in., illus., 12 + 412 pp. New York, McGraw Publishing Company, 1906. $4 net.

It is the author's purpose to describe the development of advanced practice and its principal details, to illustrate structures adapted to different conditions, to show the progress from primitive and obsolete construction to the most recent designs, in accordance with the latest requirements and improved manufacturing facilities, and to record interesting, important, and typical examples so that their principal data are easily accessible. Care has been taken to give many parallel examples of the most important class of plate girders, so as to show the differences and similarities of independent designs for corresponding service, as well as the features due to different requirements. Examples of early work are given to show the development of designs corresponding with the growth of traffic, the improvement of analytical and mathematical operations, the change from wrought iron to steel, and the great development of bridge-shop and rolling-mill practice. Still other examples of curious or absurd girders show the ingenuity or ignorance of the builder, or the peculiar conditions sometimes encountered. There is an index of bridges of two pages.

### GARBAGE CREMATORIES IN AMERICA.

By William Mayo Venable, Assoc. M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 10 + 200 pp. New York, John Wiley & Sons, 1906. $2.

The author has endeavored to place the data on crematory construction, which he has obtained since May, 1904, where others may profit by it. This study has been carried on by two methods, namely, inspection of installations actually built, and analysis of features of design as discoverable from Patent Office Records. An attempt has been made to indicate the principles of design of every type of crematory built in the United States, and to give a list of installations long enough at least to enable any interested party to look into the merits and to mark the development of any system. However, it is stated that the scope of the book is not limited to a discussion of designs. It extends to a discussion of matters that must be considered in connection with the selection of a system of garbage or refuse disposal, as well as to those matters that bear upon the selection of a crematory to meet any particular requirements. There is an index of six pages.

### THE DISPOSAL OF MUNICIPAL REFUSE.

By H. de B. Parsons, M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 10 + 186 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1906. $2.

It is stated in the preface that this book is not intended as a treatise on the designing of details for the final disposition of city refuse, but rather to define the characteristics of the materials collected, the uses to which they may be put, the quantities that may be expected, and the principles underlying their sanitary and economic handling; and to draw attention to the fact that, if a uniform method of nomenclature and record of quantities handled could be kept by the various cities, the data obtained and the information so gained would be a material advance toward the sanitary disposal of refuse. The author refers chiefly to the conditions obtaining in the City of New York, but has endeavored to arrange the material so as to make it applicable to all cities. The Contents are: Conditions; Waste Materials; Collections; Methods of Disposal; Reduction and Incineration; Economics; Snow Removal; and Practical Incineration. There is an index of three pages.

*Unless otherwise specified, books in this list have been donated by the publisher.

**SMOLEY'S TABLES.**

Parallel Tables of Logarithms and Squares, Angles and Logarithmic Functions, Corresponding to Given Bevels, and other Tables, for Engineers, Architects, etc. By Constantine Smoley. Third Edition. Leather, 7 x 5 in., illus., 9 + 332 pp. New York, The Engineering News Publishing Company, 1906. $3 net.

This work contains logarithms and squares of feet, inches and fractions thereof, expressed in decimals of a foot and varying, by $\frac{1}{32}$ of an inch, from zero to 50 feet, which in this last edition the author has undertaken to extend to 100 feet. The extended part, however, has been tabulated by steps of $\frac{1}{16}$ inch instead of $\frac{1}{32}$ inch, as the latter for lengths of more than 50 feet would have little value, if any. The parallel system of tabulation, visa the placing of the squares and logs. of the same numbers opposite each other, has been retained, this arrangement, it is stated, offering a number of advantages, namely: (1) The square and log. of a number are often needed at the same time, (2) In many calculations the square of a number is given and its log. required, or *vice versa*, the number itself being of no use to the calculator; in such cases the parallel arrangement of the tables enables the reading of the log. directly from the square, or *vice versa*, (3) The log. of the square can be obtained by multiplying its corresponding log. by 2. The Contents are: Parallel Tables of Logs. and Squares; Angles and Log. Funct.; Logs. of Numbers; Decimal Equivalents; Constants; Explanations and Examples.

**THEORY OF STEEL-CONCRETE ARCHES,**

And of Vaulted Structures. By William Cain, M. Am. Soc. C. E. Fourth Edition, Revised and Enlarged. Cloth, 6 x 4 in., illus., 212 pp. New York, D. Van Nostrand Company, 1906. 50 cents.

In this edition, the author has added a chapter on the reinforced-concrete or metal dome, thus completing the treatment (both graphical and analytical) of spherical and conical domes. In the Appendix will be found a résumé of operations, with further hints, connected with the treatment of the reinforced arch.

**ELECTRIC TRANSMISSION OF WATER POWER.**

By Alton D. Adams. Cloth, 9 x 6 in., illus., 335 pp. New York, McGraw Publishing Company, 1906. $3.

The Contents are: Water-Power in Electrical Supply; Utility of Water-Power in Electrical Supply; Cost of Conductors for Electric-Power Transmission; Advantages of the Continuous and Alternating Current; The Physical Limits of Electric Power Transmission; Development of Water-Power for Electric Stations; The Location of Electric Water-Power Stations; Design of Electric Water-Power Stations; Alternators for Electrical Transmission; Transformers in Transmission Systems; Switches, Fuses, and Circuit-Breakers; Regulation of Transmitted Power; Guard Wires and Lightning Arresters; Electrical Transmission under Land and Water; Materials for Line Conductors; Voltage and Losses on Transmission Lines; Selection of Transmission Circuits; Pole Lines for Power Transmission; Entries for Electric Transmission Lines; Insulator Pins; Insulators for Transmission Lines; Design of Insulator Pins for Transmission Lines; Steel Towers. There is an index of eight pages.

**THE PRACTICAL TESTING OF DYNAMOS AND MOTORS.**

By Charles F. Smith. Second and Enlarged Edition. Cloth, 9 x 6 in., 9 + 306 + 4 pp. Manchester, The Scientific Publishing Company. 5 shillings net.

This book is intended to serve as an elementary introduction to the study of the testing of continuous-current dynamo machinery. The use of mathematics has been avoided as far as possible, results and inferences being discussed in connection with curves obtained in the experiments. The original matter has been thoroughly revised, with additions amounting in all to about one-quarter of the present text. The section dealing with the determination of the losses in dynamos and motors has been entirely re-written, and several methods which have been shown to be of value have been added. A description of Field's test for series motors, and instructions for the parallel running of

dynamos, as well as some additional and instructive experiments on shunt, series and compound motors, form the other important additions. There is an index of three pages.

**CITY ROADS AND PAVEMENTS**

Suited to Cities of Moderate Size. By William Pierson Judson, M. Am. Soc. C. E. Third Edition, Revised. Cloth, 9 x 6 in., illus., 197 pp. New York, The Engineering News Publishing Co. $2.

The local features presented in the first edition of this book have been omitted, and modifications have been made to show the present applications of general methods, some of which have changed since 1894. The most marked change made since that time has been in the use of crushed stone for roadways of macadam and telford construction, on the improved streets of cities and villages. The examples of the State Governments of New Jersey, Massachusetts, Connecticut, and New York, in giving aid toward the construction of roads, has been followed by other States and municipalities. The result has been an increase in the best kinds of roads of broken stone, and a growing knowledge of the methods and machines by which such roads can be built and maintained. These are described under the heading, "Broken Stone Roads," without differing essentially, however, from the descriptions given in the first edition. Tables of actual instances of pavements for steep grades are given, in order that engineers may know where to find conditions similar to those in which they are interested, and where they may examine certain pavements in actual use. It is stated that the sections entitled, respectively, "Concrete Base," "Block Stone," "Wood," "Vitrified Brick," "Asphalt," "Bituminous Macadam," and "Broken Stone," are made to accord with the latest records of methods and costs, illustrations and tables being used for the sake of brevity. There is an index of nine pages.

**THE MANUFACTURE OF CONCRETE BLOCKS:**

The Use in Building Construction. By H. H. Rice. Wm. M. Torrance, and others. Cloth, 9 x 6 in., illus., 122 pp. New York, The Engineering News Publishing Company, 1906. $1.50 net.

In this book the author presents a discussion of the technology of concrete-block manufacture. The details of the industry are reviewed; the choice of locations for concrete-block factories, the plant and equipment required, the selection of moulding machines and processes, the manufacture, curing, shipping and storing of blocks, and, finally, their use in building construction are discussed. There is an index of six pages.

**THE ADJUSTMENTS OF THE ENGINEER'S TRANSIT AND LEVEL.**

By Howard C. Ives, Jun. Am. Soc. C. E. Second Edition. Boards, 7 x 4 in., illus., 15 pp. New York, John Wiley & Sons, 1906. 25 cents net.

The author states that it is his intention to give the principles of the correct adjustment of surveying instruments so that the engineer may actually make nearly all the adjustments, rather than merely test them without touching the screws. The Contents are: Introduction; the Bubble Tube; The Reticule; Line of Collimation; Vertical Axis; The Adjustments of the Y Level; To Bring the Axis of the Bubble into the Same Plane as the Axis of the Telescope; To Make the Line of Collimation Parallel to the Axis of the Bubble; To Make the Axis of the Bubble Perpendicular to the Vertical Axis of the Instrument; The Transit; To Make the Axis of the Plate Levels Perpendicular to the Vertical Axis of the Instrument; To Make the Line of Collimation Revolve in a Vertical Plane when the Telescope is Turned on its Horizontal Axis; To Make the Axis of the Telescope-bubble Parallel to the Line of Collimation; To Make the Vernier of the Vertical Circle Read Zero when the Line of Collimation is Horizontal; Field Notes on Adjusting the Transit.

**HIGH-TENSION POWER TRANSMISSION.**

Second Volume. A Series of Papers and Discussions Presented at the International Electrical Congress in St. Louis, 1904. Cloth, 9 x 6 in., illus., 6 + 315 pp. New York, McGraw Publishing Company, 1906. $2.50.

These papers have been gathered from fields of practical experience; therefore they cover phases of the subject considered from various points of view. On account of this diversity of topic and treatment, they become particularly

valuable to those who wish to learn, at first hand, the facts which engineers have learned from their daily experience. It is not to be expected, therefore, that the views presented as to details of construction will agree and form a systematic treatment of the present state of power transmission. This volume is valuable in that it selects, from sources not always accessible, opinions recently delivered by experts regarding some highly important topics, and combines them in a form easily consulted when necessary. There is an index of subjects and one of authors, both included in five pages.

**INDUSTRIAL FURNACES AND METHODS OF CONTROL.**

By Emilio Damour: Authorized Translations, with Additions, by A. L. J. Queneau. Cloth, 9 x 7 in., illus., 11 + 317 pp. New York and London, The Engineering and Mining Journal, 1906. $4.

The purpose of the present work is to study the means of improving the utilization of heat and of decreasing, through recuperation, the loss of heat in waste products. To accomplish this, the supposition is made that the furnaces are governed by the physical laws of combustion and exchange of calorics, each phenomenon taking place completely. At first the practical considerations, as that of time, are not taken into account. In a word, a Theory of Recuperation is built, which allows of the classification of furnaces according to their maximum efficiency. This constitutes the first part of the book. The second part introduces data obtained by the experimental study of furnaces. The first part is a translation of Emilio Damour's "Le Chauffage Industriel et les Fours à Gas," supplemented with diagrams, plates, tables, and numerical problems, by A. L. J. Queneau. The second part has been written by Mr. Queneau and M. N. Bolles to cover the field of Pyrometry, Gas Analysis, Calorimetry and Fuel Analysis, which has only been touched upon in the work of Damour. Chapters have also been added, which give typical examples of methods to be followed in designing the various parts of gas-recuperative furnaces. It is the author's aim to be helpful to the works manager and the theoretician. There is an index of ten pages and a bibliography.

**MANUAL OF EXAMINATIONS FOR ENGINEERING POSITIONS**

In the Civil Service of the City of New York.. Questions and Answers in 3 volumes. Vol. I, Part I, Axeman. Paper, 9 x 6 in., illus., 28 pp. New York, The Engineering News Publishing Company, 1906. 60 cents.

These questions and answers are to be issued in three volumes, each containing several parts. Vol. I, Axeman, Chainman and Rodman, Leveler and Transitman and Computer; Vol. II, Assistant Engineer; Vol. III, Draftsman and Inspector. The first few pages of this volume contain previous examination questions, following which are blank pages for the addition of new sets and a section containing typical questions and answers with illustrations and problems.

**HEAT AND LIGHT**

From Municipal and Other Waste. By Joseph G. Branch. Cloth, 8 x 6 in., illus., 7 + 305 pp. St. Louis, Wm. H. O'Brien Printing and Publishing Co., 1906. $3. (Donated by the National Equipment Company.)

There is no more serious menace to the health of any community than its refuse, nor a greater necessity to the comfort and welfare of its citizens than plenty of heat and light at a moderate cost. The author states that the object of this book is to call the attention of public officials and engineers to the efforts which, for the last twenty-five years, have been made in this and other countries to meet these requirements by better systems of garbage disposal and by the production of more light and heat at less cost. How far American cities are behind those of Europe in this respect is shown by comparison, and the reason given for the discrepancy is the utilization, or lack of utilization, of the incinerated wastes for the production of heat and light. The book is of much value to sanitary and municipal engineers in that it treats of reduction and incinerating methods of refuse disposal as practiced both in Europe and the United States. The different heating and lighting systems and plants are fully described, and much valuable data obtained by the author from various municipalities, in which such sytems have been installed, are also given. There is a table of contents, but no index.

### THE TRANSMISSION OF HEAT

Through Cold-Storage Insulation: Formulas, Principles, and Data Relating to Insulation of Every Kind; A Manual for Refrigerating Engineers. By Charles P. Paulding. Cloth, 8 x 5 in., illus., 3 + 41 pp. New York, D. Van Nostrand Company, 1905. $1.00 net.

It is stated in the preface that all treatises on artificial heating have been based on the laws and experiments given by the French physicist, Péclet, in his book "Traite de la Chaleur." These laws and experiments are equally applicable to the art of refrigeration, and it is the purpose of the author to present them, in this book, in a convenient form, together with additional data required for modern practice. The Contents are: General Principles; Radiation; Air Contact; Conduction; Formula for a Homogeneous Wall; Formula for a Compound Wall; Formula for a Wall Containing an Air-Space; Floors and Ceilings; Experimental Proof of the Formulas; and Insulation of Brine-Pipes. There is no index.

### MECHANICS—PROBLEMS FOR ENGINEERING STUDENTS.

By Frank B. Sanborn, M. Am. Soc. C. E. Second Edition, Revised and Enlarged. Cloth, 8 x 6 in., illus., 8 + 194 pp. New York, John Wiley & Sons, 1906. $1.50.

The author states that there is an opinion among engineers that students, as a rule, are not well-grounded in the practical problems of Mechanics, that they know more of the theory and mathematical deductions than of their practical applications. It is believed that the necessary elementary principles will be best understood and best remembered by the solution of numerous problems illustrative of every-day engineering practice, and with this in view, the author has endeavored, in this book, to present, from actual conditions, many practical problems, together with definitions and solutions of typical problems. These have been divided into sections, one problem being solved at the beginning of each section so as to explain the methods used in similar cases. An effort has been made throughout the book to simplify, few methods being presented; the calculus being used only when necessary. The "gravitation system" of units, known as the engineer's system, has been used exclusively. The problems and solutions are arranged under the following heads, several new chapters having been added to each section in this edition: I. Work—Foot-Pounds; Horse-Power; Energy; II. Force—Forces Acting at a Point; Moments for Parallel Forces; Couples; Stresses; Center of Gravity; Friction; III. Motion—Uniform Acceleration; Relative Velocity; Distance, Velocity, Friction, Angle of Inclination; Projectiles; Pendulums; Impact; IV. Review—Practical Problems; Examinations; Answers; Definitions; Tables. There is an index of two pages.

### EXPÉRIENCES SUR LE TRAVAIL DES MACHINES-OUTILS

Pour les Métaux. Par C. Codron. 2e Fascicule: Forage. Paper, 11 x 9 in., illus., 552 pp. Paris, H. Dunod et É. Pinat, Éditeurs, 1906. 25 francs.

In 1902, the author published the first part of this book, which part consisted of a general study of machine-tools. In this, the second volume, M. Codron has taken the operation of boring and the various forms of drills for his subjects. In the first chapter he shows the rational construction of various ordinary and special drills in order to make the importance of the helicoidal drill stand out. Minute and numerous observations are made of blades and boring-wheels for deep borings. The second chapter, which treats of the bore-chips, shows how the conformations vary with the different metals and the different arrangement of the tools, which permits one to judge quickly as to the maintenance of the tool and the nature of the metal. The force and strength of boring are analyzed in the various phases of operation, and lead to the development of extended theories. The formulas summed up are accompanied by coefficients shared by the different metals, in order to permit of their ordinary application. The apparatus for tests for boring are described, with results of tests made on different metals. These tests have permitted the deduction of general rules for cutting metals into very thin sheets. Repeated tests of cutting with blades are also given, and the coefficients for the different metals are compared with those for boring proper. Tests of drilling machines of all kinds, mechanical and electrical, fixed and movable, follow. Drills for steel, accelerated by heavy discharge, have been tried in order to show their great value in application. There is a table of contents, but no index.

**SHAFT GOVERNORS.**

By W. Trinks and C. Housum. Cloth, 6 x 4 in., illus., 2 + 97 pp. New York, D. Van Nostrand Company, 1906. 50 cents.

Experience with shaft governors shows a wide difference between the actual practice and a superficial theory. It is stated that it was the desire of solving this difference which prompted the authors to study the question in all its phases. The contents of this volume have grown out of notes and formulas made for the immediate use of the authors, and while the book treats of the statics and dynamics of shaft governing, it does not claim to have covered the whole subject. Purely descriptive matter has been omitted, and the formulas have been kept as general as possible, so that they may be applied to any form of governor. Some examples are given to illustrate the application of the obtained formulas, but the main object of the authors has been to derive certain simple rules and coefficients from these formulas for every-day use in connection with the type of governor which has been adopted as a standard by any one builder. The Contents are: Centrifugal Moment; Centrifugal Moment Caused by Inertia of Valves and Valve Gear; Mass of Valves Reduced to Center of Eccentric; Reacting Moment caused by Friction of Valves; Friction of Eccentric Strap; Spring Moment; Influence of Mass of Helical Governor Springs; Numerical Examples; Tod Governor; and the Thompson Governor. There is no index.

**REPORT OF THE ELECTRIC RAILWAY TEST COMMISSION**

To the President of the Louisiana Purchase Exposition. Cloth, 9 x 6 in., illus., 13 + 621 pp. New York, McGraw Publishing Company, 1906. $6 net. (Donated by the Electric Railway Test Commission.)

This report is a review of the work done under the auspices of the Electric Railway Test Commission, and is a valuable contribution, not only to the electric railway profession, but to engineering literature as well. It is stated that the organization of this Commission was due to the recognition by the officials of the Louisiana Purchase Exposition of the fact, that the large and varied exhibit of electric railway apparatus gathered together at the Exposition, offered an exceptional opportunity for a comprehensive series of tests which would be of value both to the manufacturer and user of electrical machinery. The Commission itself was made up of men representing all branches of the electric railway service, and was assisted in its work by an Executive Committee and a test corps of men selected from the graduates of various universities. It also had the co-operation of the Exposition officials, the Executive Committee of the American Street Railway Association, the United States Bureau of Standards and leading manufacturers of electrical railway apparatus. The tests made and reported include service, acceleration and braking tests on single and double-truck city cars; compressor station tests of a storage-air system of braking; tests of a storage battery industrial locomotive; tests of alternating-current losses in steel rails and in other steel and iron sections; and tests of alternating-current losses in track. Besides these tests, which were made at St. Louis, the Indiana Union Traction Company contributed the use of its track for high speed and heavy traction tests, from which data of great value to steam and electric railway interests were obtained. The book is fully illustrated and has an index of seven pages.

**JAHRBUCH FÜR DAS EISENHÜTTENWESEN.**

(Ergänzung zu *Stahl und Eisen.*) Ein Bericht über die Fortschritte auf allen Gebieten des Eisenhüttenwesens im Jahre 1903. Im Auftrage des Vereins deutscher Eisenhüttenleute bearbeitet von Otto Vogel. IV. Jahrgang. Cloth, 10 x 7 in., illus., 16 + 464 pp. Düsseldorf, A. Bagel, 1906. 10 marks.

This Yearbook, like its predecessors, is issued as a supplement to *Stahl und Eisen*. It is a review of German and foreign periodical literature treating of the metallurgy of iron for the year 1903. Its scope is enlarged from year to year, the number of technical periodicals reviewed for 1903 being 141 as against 134 for 1902, almost half of these being other than German periodicals. Illustrated abstracts of articles of particular importance are given in addition to their sources. The bibliographies are arranged by subject, and author and subject indices are also given.

**THE CAR BUILDERS' DICTIONARY:**

An Illustrated Vocabulary of Terms which Designate American Railroad Cars, Their Parts, Attachments and Details of Con-

struction, with Definitions and Illustrations of Typical British Practice in Car Construction. Compiled for the Master Car Builders' Association by Rodney Hitt, Jun. Am. Soc. C. E., Assisted by Messrs. C. A. Seley, H. F. Ball and J. E. Muhlfeld. 1906 Edition. Morocco, 12 x 8½ in., illus., 568 pp. New York, *The Railroad Gazette,* 1906. $6.00. (Donated by the Compiler.)

This dictionary was first published in 1879, subsequent revised editions having been issued in 1884, 1895 and 1903. In this, the latest edition, the original idea of "an illustrated book, defining the proper terms or names of each and every part used in the construction of railway cars, and a description of the use of the same" has been carefully carried out and brought up to date. It is stated in the preface that during the last three years the changes in the design and construction of cars have been greater and of a more radical nature than during any of the periods intervening between previous editions. Comparison of this and the 1903 edition will show that nearly half of the former engravings have been replaced by illustrations of new and improved devices, and that nearly 200 pages of illustrations have been added. The number of figures has also been increased from 4 971 to 6 344. The general arrangement of the book has been adhered to with the exception of some minor changes. All references to devices and parts of devices belonging directly to the locomotive or tender have been omitted in view of the early publication of a Locomotive Dictionary along lines similar to this book. The illustrations of typical British cars are an addition to the subject-matter. These illustrations give a good general view of the dimensions and principal constructive features of the standard designs of cars used in Great Britain, but it has been impossible to illustrate them in as great detail as has been done with American practice. This part of the dictionary should be of great convenience to manufacturers of railroad equipment, especially to those who are seeking foreign markets. Superfluous and obsolete matter in definitions has been eliminated, the wording of definitions of such terms as have gradually taken on a new meaning having been changed, and definitions of terms and parts which have come into general usage during the last few years having been added. There is an index of two pages to the engravings, which is arranged alphabetically under general heads.

**ILLUSTRATED TECHNICAL DICTIONARY IN SIX LANGUAGES.**

English, German, French, Russian, Italian, Spanish. Compiled by K. Deinhardt and A. Schlomann. Vol. I, The Elements of Machinery and the Tools Most Frequently used in Metal and Wood Working. Cloth, 7 x 4 in., illus., 403 pp. New York, McGraw Publishing Company. $2.

This volume is the first of a series of technical dictionaries to be issued by the compilers, in which various industries are to be treated in a detailed manner by specialists. They are to be published in the form of pocket dictionaries and are intended to aid the engineer in the reading and study of technical articles and the terms contained therein. By the arrangement of the subject-matter they are intended to be of use as handbooks as well as dictionaries. Sketches, formulas and symbols, which were used for ascertaining the translations of technical terms, are to be retained in the text, and, as many of these translations were made in offices and workshops, they are to be here collected and used for the first time. Each dictionary is to contain three parts, namely, the index, the systematic arrangement of the matter, and an alphabetical index of words in five languages. Only such terms as are in common use are to be given, those applying to designs which are out of date, or merely of historic value, are to be omitted. As explained in the title, this volume treats of the elements of machinery and of the tools most frequently used in metal and wood-working, with an appendix containing terms used in the drafting-room. Only such tools as are found in every machine shop and which form a part of elementary machine construction are given. Small tools and machine tools are to be treated in a separate volume.

**THE CORROSION AND PROTECTION OF METALS,**

With Special Reference to the Preservation of Engineering Structures. By A. Humboldt Sexton. Cloth, 7 x 5 in., 5 + 147 pp. Manchester, The Scientific Publishing Company. 5 shillings net.

The question of the cause and prevention of the corrosion of metals is of vital importance to engineers generally. The quantity of metal used for structural purposes is increasing annually, but the conditions under which it is used seem to indicate that little care is taken for its protection, and that engineers and architects are not sufficiently alive to the dangers of corrosion. The author

states that these notes have been written to supply, to some extent, the need for information on this subject, and he intends, in this book, to discuss briefly the corrosion of metals in common use under the conditions in which they are generally used, and the means that have been found most efficient for protecting them. He has made a number of experiments as the only possible means of elucidating obscure points; these are embodied in the text. While it is not claimed that these notes are complete, nevertheless they give all that is known of the present condition of the subject. The Contents are: Rusting of Iron and Steel; Protection of Iron and Steel from Atmospheric Corrosion; Atmospheric Corrosion of Other Metals; Corrosion of Metals by Corrosive Gases; Corrosion of Metals by Water and Other Liquids; Corrosion of Iron and Steel by Sea Water; Corrosion of Copper and Brass by Sea Water.

## Gifts have also been received from the following:

Am. Assoc. for the Advancement of Sci. 1 vol.
Am. Gas Light Assoc. 1 vol.
Am. Inst. of Min. Engrs. 1 bound vol.
Am. Iron and Steel Assoc. 1 vol.
Am. Ry. Assoc. 1 pam.
Am. Soc. for Testing Materials. 1 vol.
Am. Soc. for the Prevention of Cruelty to Animals. 1 vol.
Am. Soc. of Mech. Engrs. 1 bound vol.
Am. Soc. of Municipal Impvts. 2 vol.
Am. Soc. of Refrigerating Engrs. 1 pam.
Am. Street and Interurban Ry. Assoc. 1 bound vol.
Architectural Record Co. 1 bound vol.
Art Comm. of the City and County of Denver. 1 pam.
Assoc. Amicale des Anciens Elèves de l'Ecole Centrale des Arts et Manufactures. 1 vol.
Assoc. Parisienne des Propriétaires d'Appareils à Vapeur. 1 vol.
Assoc. of Am. Portland Cement Mfrs. 12 pam.
Assoc. of Civ. Engrs. of Cornell Univ. 1 vol.
Baltimore, Md.—Water Board. 1 bound vol.
Bangor, Me.—Water Board. 1 vol.
Bengal, India—Public Works Dept. 2 bound vol.
Bilbao, Spain—Junta de Obras del Puerto. 1 vol.
Bombay, India—Public Works Dept. 1 vol.
Boston, Mass.—City Auditor. 1 bound vol.
Boston, Mass.—Statistics Dept. 1 vol., 1 pam.
Boston Soc. of Civ. Engrs. 1 pam.
Brit. Assoc. for the Advancement of Sci. 1 bound vol.
Brit. Columbia—Dept. of Mines. 5 bound vol.
Brit. Fire Prevention Committee. 1 pam.
Brockton, Mass.—Board of Water Commrs. 1 pam.
Buffalo, N. Y.—Bureau of Water. 1 vol.
Buffalo, N. Y.—Dept. of Public Works. 1 vol.
Buffalo, N. Y.—Chamber of Commerce. 5 pam.
Caird, J. M. 6 pam.
Cambridge, Mass.—Mayor. 1 bound vol.
Canada—Dept. of Marine and Fisheries. 1 pam.
Canada—Dept. of Rys. and Canals. 1 vol.
Canada—Dept. of the Interior. 6 maps.
Canadian Min. Inst. 1 vol.
Cape of Good Hope—Dept. of Public Works. 1 pam.
Cape of Good Hope—Gen. Mgr. of Rys. 2 vol.
Chemin de Fer de Paris à Lyon et à la Méditerranée. 1 vol.
Chicago, Ill.—Bureau of Statistics. 1 pam.
Chicopee, Mass.—Mayor. 1 bound vol.
Colby, A. L. 1 pam.
Coll. Toscano degli Ingegneri ed Architetti, Firenze. 1 pam.
Colo.—Agri. Exper. Station. 9 pam.
Colo.—State Agri. Coll. 1 vol.
Columbia, S. C.—Civic Impvt. League. 1 pam.
Conn.—State Board of Health. 1 bound vol.
Conn. Soc. of Civ. Engrs. 1 vol.
Cooper, Theodore. 1 pam.
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**Electricity Meters.** By Henry G. Solomon. London, Charles Griffin & Company, Limited, 1906.

**Mittheilungen aus dem Mechanisch-Technischen Laboratorium der K. Polytechnischen Schule in München;** Vol. 1–29. Von J. Bauschinger. München, Theodor Ackermann, 1873–1904.

**Public Health, Papers and Reports, Vol. 31, Pts. 1-2;** Presented at the Thirty-third Annual Meeting of the American Public Health Association, Boston, Mass., Sept., 1905. Columbus, Ohio, American Public Health Association, 1906.

**Le Bois; Fascicule 1-2.** Par J. Beauverie. Paris, Gauthier-Villars, 1905.

**American Plumbing Practice, from *The Engineering Record.*** New York, Engineering Record, 1896.

**Applied Mechanics.** By Gaetano Lanza. Ninth Edition, Revised. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1905.

**Architectural Iron and Steel.** By W. H. Birkmire. Third Edition. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1905.

**Resistance and Propulsion of Ships.** By W. F. Durand. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1903.

**Inspection of the Materials and Workmanship Employed in Construction.** By A. T. Byrne. Second Edition. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1905.

**Steam-Boilers.** By C. H. Peabody and E. F. Miller, M. Am. Soc. C. E. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1905.

**A Treatise on Arches.** By M. A. Howe, M. Am. Soc. C. E. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1897.

**Graphics for Engineers, Architects and Builders;** Part I.—Roof-Trusses; Part II.—Bridge-Trusses; Part III.—Arches. By C. E. Greene. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1903–05.

**Concrete-Block Manufacture.** By H. H. Rice. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1906.

**Valve-Gears for Steam-Engines.** By C. H. Peabody. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1906.

**Modern Electricity.** By James Henry and Karl J. Hora. Chicago, Laird & Lee, 1904.

**Cassell's Building Construction.** By Henry Adams. London, Paris, New York and Melbourne, Cassell and Company, Limited, 1906.

**Constructional Steelwork.** By A. W. Farnsworth. London, Charles Griffin & Company, Limited, 1905.

**Railways and Their Rates.** By Edwin A. Pratt. New York, E. P. Dutton and Company, 1906.

**The Locomotive up to Date.** By Chas. McShane. Chicago, Griffin & Winters, 1906.

**Trow Business Directory of Greater New York,** Five Boroughs Combined, 1906. New York, Trow Directory, Printing and Bookbinding Co.

**Manual of Assaying,** Gold, Silver, Lead, Copper. By Walter Lee Brown. Chicago, E. H. Sargent & Co.; London, E. & F. N. Spon, Ltd., 1905.

**Forscherarbeiten auf dem Gebiete des Eisenbetons, Heft IV;** Formänderungsarbeit der Eisenbetonbauten bei Biegung. Von Kazimir Grabowski. Berlin, Wilhelm Ernst & Sohn, 1906.

**Papers on Mechanical and Physical Subjects.** By Osborne Reynolds. Vol. II–III. Cambridge, The University Press, 1901–03.

**Der Brückenbau. Handbuch der Ingenieurwissenschaften, II Band, Fünfte Abteilung.** Herausgegeben von Th. Landsberg. Leipzig, Wilhelm Engelmann, 1906.

**Der Grubenausbau.** Von Hans Bansen. Berlin, Julius Springer, 1906.

**Tunnel Shields and the Use of Compressed Air in Subaqueous Works.** By William Charles Copperthwaite. New York, D. Van Nostrand Co., 1906.

**Notes on Electrochemistry.** By F. G. Wiechmann. New York, McGraw Publishing Company, 1906.

**The Ventilation, Heating and Lighting of Dwellings.** By J. W. Thomas. London, New York and Bombay, Longmans, Green and Co., 1906.

**Résistance des Matériaux Appliquée aux Constructions, Vol. II.** Par Ernest Aragon. Paris, H. Dunod et E. Pinat, 1906.

**A Practical Treatise on Bridge-Construction,** being a Text-Book on the Design and Construction of Bridges in Iron and Steel. T. Claxton Fidler. Third Edition, Enlarged and Revised. London, Charles Griffin and Company, Limited, 1901.

**Vergleichende Morphologie und Biologie der Pilze;** Mycetozoen und Bacterien. Von A. De Bary. Leipzig, Wilhelm Engelmann, 1884.

**Single-Phase Commutator Motors.** By Franklin Punga. Translated from the German by R. F. Looser. London, Whittaker & Co., 1906.

**Our Waterways.** By Urquhart A. Forbes and W. H. R. Ashford. London, John Murray, 1906.

**A Practical Manual of Tides and Waves.** By W. H. Wheeler. London, Longmans, Green & Co., 1906.

**Ciments et Chaux Hydrauliques;** Fabrication, Propriétés, Emploi. Par E. Candlot. Troisième Edition. Paris, Ch. Béranger, 1906.

**Elektrotechnik in Einzeldarstellungen.** Achtes Heft. Herausgegeben von Gustav Benischke: Lichtstrahlung und Beleuchtung. Von Paul Högner. Braunschweig, Friedrich Vieweg und Sohn, 1906.

**The Principles of Electric Wave Telegraphy.** By J. A. Fleming. New York, Longmans, Green & Co., 1906.

**An Elementary Treatise on Phototopographic Methods and Instruments.** By J. A. Flemer. New York, John Wiley & Sons, 1906.

**Marine Boilers:** Their Construction and Working, Dealing More Especially with Tubulous Boilers. Based on the Work by L. E. Bertin. Translated and Edited by Leslie S. Robertson; with a New Chapter on "Liquid Fuel" by H. C. Anstey. Second Edition. New York, D. Van Nostrand Company, 1906.

**American Street Railway Investments, Vol. 13, 1906.** New York, McGraw Publishing Company, 1906.

**Steam-Boiler Explosions** in Theory and in Practice. By R. H. Thurston. Third Edition. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1903.

**Hydraulic Cement**; its Properties, Testing and Use. By Frederick T. Spalding. Second Edition. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1906.

**The Field Engineer.** By William Findlay Shunk. Seventeenth Edition. New York, D. Van Nostrand Company, 1905.

**Appendices to the Report of the Royal Commission** on London Traffic, with Index. Vol. IV. London, Wyman and Sons, Limited, 1906.

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## SUMMARY OF ACCESSIONS.

From May 8th to Aug. 4th, 1906.

| | |
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| Donations (including 321 duplicates) | 853 |
| By purchase | 52 |
| Total | 905 |

## MEMBERSHIP.

### ADDITIONS.

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| ADAMS, HENRY SEWALL. 71 Ames Bldg., Boston, Mass. | | June 6, 1906 |
| AFFELDER, LOUIS JACOB. Contr. Mgr., Am. Bridge Co. of N. Y., Frick Bldg., Pittsburg, Pa | Jun. | Feb. 4, 1896 |
| | Assoc. M. | June 5, 1901 |
| | M. | June 5, 1906 |
| BERQUIEST, AXEL SAMUEL FREDERICK. 517 Bedford Ave., Brooklyn, N. Y. | | June 6, 1906 |
| BLOOM, J GEORGE. Engr. of Maintenance, C., R. I. & P. Ry. Co., 915 Fillmore St., Topeka, Kans. | | July 9, 1906 |
| CAHILL, WALTER JOHN. Second Vice-Pres. and Chf. Engr., Great Lakes Dredge & Dock Co., 1322 Chamber of Commerce Bldg., Chicago, Ill. | | June 6, 1906 |
| CLARK, WATSON GEROULD. Tenafly, N. J. | | July 9, 1906 |
| CULLEN, JAMES FRANCIS. Asst. Engr. of Constr., P. R. R. Co., Havre de Grace, Md. | | May 2, 1906 |
| DAVIS, NOAH WILSON. Harrisonburg, Va. | | July 9, 1906 |
| DOCKWEILER, JOHN HENRY. 1969 Jackson St., San Francisco, Cal. | | May 2, 1906 |
| DUNHAM, WILLIAM ROBERT, JR. Asst. Engr., Consolidated Ry. Co., Room 215, Malley Bldg., New Haven, Conn. | | July 9, 1906 |
| ELDRIDGE, CHAUNCEY. 53 State St., Boston, Mass. | | May 2, 1906 |
| FITCH, HOWARD AUGUSTUS. Chf. Engr., Minneapolis Steel & Machinery Co., 3013 Portland Ave., Minneapolis, Minn. | | July 9, 1906 |
| FRANKLIN, BENJAMIN. Civ. and Cons. Engr. (Franklin & Clarke), 907 Crozer Bldg., Philadelphia, Pa. | Assoc. M. | April 1, 1903 |
| | M. | June 5, 1906 |
| GIDDINGS, FREDERICK. City Engr., Atchison, Kans. | | June 6, 1906 |
| GILLESPIE, RICHARD HENWOOD. Asst. Engr., Bureau of Highways, Bronx (Res., 2774 Briggs Ave., Bedford Park), New York City | Assoc. M. | Oct. 3, 1900 |
| | M. | June 5, 1906 |
| HALLIHAN, JOHN PHILIP. Asst. to Pres. and Chf. Engr., F. C. R. G., S. M. y P., P. O. Box 687, El Paso, Tex. | Assoc. M. | April 4, 1900 |
| | M. | June 5, 1906 |
| HENCH, NORMAN MACPHERSON. Engr. of Track Appliances, Carnegie Steel Co., Room 315, Carnegie Bldg., Pittsburg, Pa. | | May 2, 1906 |
| HEPBURN, FREDERICK TAYLOR. Gen. Mgr., Lima & Toledo Traction Co., Lima, Ohio | | June 6, 1906 |
| HIGGINS, HORACE LONGUET. Care, Manila Ry. Co., Ltd., P. O. Box 448, Manila, Philippine Islands | | May 2, 1906 |

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| HILLIARD, FOSTER HAVEN. Supt., Dredging Operations, Mississippi River Comm., Box 217, Memphis, Tenn. | Assoc. M.<br>M. | Mar. 6, 1901<br>May 1, 1906 |
| HOGELAND, ALBERT HARRISON. 813 Goodrich Ave., St. Paul, Minn | | May 2, 1906 |
| KENRICK, ROBERT BOTELER. Chf. Draftsman, Dominion Bridge Co., Montreal, Que., Canada | | July 9, 1906 |
| KINNEAR, WILSON SHERMAN. Asst. Gen. Mgr., Mich. Cent. R. R. Co., Detroit, Mich. | | July 9, 1906 |
| KNIGHT, CHARLES WILLIAM. Rome, N. Y. | | July 9, 1906 |
| LATEY, HARRY NELSON. Elec. Engr., Interborough Rapid Transit Co., 2433 Park Row Bldg., New York City | | June 6, 1906 |
| LOVELL, FREDERICK WILLIAM. Vice-Pres. and Chf. Engr., The McMyler Mfg. Co., 437 Franklin Ave., Cleveland, Ohio. | | June 6, 1906 |
| MEBUS, CHARLES FILLMORE. 908 Land Title Bldg., Philadelphia, Pa. | | May 2, 1906 |
| MONCURE, WILLIAM AUGUSTUS. Right of Way Agt., P. R. R., Broad St. Station, Philadelphia, Pa. | Jun.<br>Assoc. M.<br>M. | June 21, 1894<br>Oct. 7, 1896<br>June 5, 1906 |
| MUSSON, EUGENE FRANCIS. Engr. and Surv., 12 Sheldon St., Norwich, N. Y. | | May 2, 1906 |
| NEELY, WILLIAM RIDLEY. West Point, N. Y. | | July 9, 1906 |
| NYEBOE, MARIUS IB. Nörrevold 28, Copenhagen, Denmark | | July 9, 1906 |
| ORROK, GEORGE ALEXANDER. Chf. Draftsman and Asst. to Gen. Mgr., New York Edison Co., 226 East 17th St., Flatbush, N. Y. | | June 6, 1906 |
| PARKER, ORLANDO KENTON. 1116 Braly Bldg., Los Angeles, Cal. | | June 6, 1906 |
| PEIMBERT, ANGEL. Puente Alvarado No. 15, City of Mexico, Mexico. | | July 9, 1906 |
| PERKINS, CHARLES EZRA. Chf. Engr., Public Works of Ohio, Columbus, Ohio. | | June 6, 1906 |
| SAWYER, WALTER HOWARD. Lewiston, Me. | | May 2, 1906 |
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| SMITH, ROBERT COLFAX. 1106 The Rookery, Chicago, Ill. | | July 9, 1906 |
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| WAGNER, JOSEPH CHRISTIAN. Surv. and Regulator, 9th Survey Dist., Dept. of Public Works, Philadelphia; Office, Chelton Ave. and Greene St., Germantown (Res., 1539 North 12th St.), Philadelphia, Pa. | Assoc. M.<br>M. | June 7, 1899<br>June 5, 1906 |

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| AVAKIAN, JOHN CASPAR. Asst. Engr., U. S. Reclamation Service, 623 Citizens National Bank Bldg., Los Angeles, Cal. | July 9, 1906 |
| BACKES, WILLIAM JAMES. Chf. Engr., The Central New England Ry. Co., 59 Spruce St., Hartford, Conn. | Jun. May 31, 1904<br>Assoc. M. July 9, 1906 |
| BAYLIS, ARTHUR RAYMOND. Mech. Asst. Engr., Hudson Companies, 2416 Clarendon Rd., Flatbush, N. Y. | June 6, 1906 |
| BEAL, GEORGE SAFFORD. Care, Knight & Hopkins, Rome, N. Y. | June 6, 1906 |
| BLISS, EDWIN PACKARD. 120 Milk St., Boston, Mass. | July 9, 1906 |
| BROOKS, MILES ELIJAH. Barnesdale, Ont., Canada | July 9, 1906 |
| CHAPMAN, PAUL. 122 Montague St., Brooklyn, N. Y. | June 6, 1906 |
| CLARK, WARREN VESTER. 2132 University Ave., Berkeley, Cal. | Mar. 7, 1906 |
| COLNON, REDMOND STEPHEN. Gen. Contr. (Fruin & Colnon), 615 Laclede Bldg., St. Louis, Mo. | July 9, 1906 |
| CONZELMAN, JOHN EDWARD. Queen Anne's Chambers, Westminster, London, S. W., England. | April 4, 1906 |
| COTHRAN, THOMAS WHITE. Care, Raleigh & Pamlico Sound Ry., Raleigh, N. C. | July 9, 1906 |
| COVELL, VERNON ROYCE. Room 25, Court House, Pittsburg, Pa. | Mar. 7, 1906 |
| CRYDER, HOWARD MICHAEL. Fullerton Bldg., St. Louis, Mo. | June 6, 1906 |
| DEBERARD, WILFORD WILLIS. Care, Board of Public Service, Columbus, Ohio. | May 2, 1906 |
| DEMOTT, CHARLES LEONARD. Asst. Engr., Excelsior Wooden Pipe Co., Lynchburg, Va. | June 6, 1906 |
| DOTEN, LEONARD SMITH. 410 A St., N. E., Washington, D. C. | July 9, 1906 |
| EHRBAR, LOUIS HARVEY. Engr., Subway Constr., Plant Dept., N. Y. Telephone Co., 15 Dey St., New York City. | May 2, 1906 |
| FITCH, SQUIRE EARNEST. Div. Engr., Buffalo & Susquehanna R. R. Co., Galeton, Pa. | July 9, 1906 |
| FRENCH, MANSFIELD JOSEPH. Engr., M. of W., Utica & Mohawk Val. Co., Electric Railway Bldg., Utica, N. Y. | July 9, 1906 |

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| GOLDENBERG, MAURICE. Chf. Engr., Trussed Concrete Steel Co., Wayne Bank Bldg., Detroit, Mich. | | Feb. 7, 1906 |
| GOODMAN, JOSEPH. 157 West 111th St., New York City. | | June 6, 1906 |
| GREENSFELDER, ALBERT PRESTON. Supt., Fruin & Colnon, Contrs., 10738 Columbia Bottom Rd., St. Louis, Mo. | Jun. | May 3, 1904 |
| | Assoc. M. | May 2, 1906 |
| HELLER, JOHN WALTER. 164 Prospect Park West, Brooklyn, N. Y. | | June 6, 1906 |
| HOOD, JOHN MIFFLIN, JR. Prin. Asst. Engr., United Railways & Elec. Co. (Res., 1118 N. Calvert St.), Baltimore, Md. | Jun. | May 31, 1904 |
| | Assoc. M. | June 6, 1906 |
| IMMEDIATO, GERARDO. Engr., Power House Constr., Mexican Light & Power Co., Necaxa, Puebla, Mexico. | | July 9, 1906 |
| JOHANNSEN, OSKAR AUGUSTUS. 919 East State St., Ithaca, N. Y. | | May 2, 1906 |
| KABASHIMA, MASAYOSHI. Eng. Dept., City Hall, Tokyo, Japan | | May 2, 1906 |
| KEYS, EDWARD ALLEN. Linden, Md. | | July 9, 1906 |
| LARMON, FRANK PERRY. Asst. Engr., Dept. of State Engr., Waterford, N. Y. | | July 9, 1906 |
| LEWIS, RANSOME TEDROWE. Care, Empire Bridge Co., Elmira, N. Y. | | June 6, 1906 |
| LEX, WASHINGTON IRVING. 1508 N. 19th St., Philadelphia, Pa. | | May 2, 1906 |
| LINNELL, HERBERT PRESCOTT. Care, Isthmian Canal Comm., Cristobal, Canal Zone, Panama | | May 2, 1906 |
| MARKWART, ARTHUR HERMANN. Chf. Engr., Syndicate Water Co., Berkeley, Cal. | | July 9, 1906 |
| MELICK, NEAL ALBERT. Asst. Engr., Tidewater Ry., Chf. Engr.'s Office, Norfolk, Va. | Jun. | Dec. 2, 1902 |
| | Assoc. M. | July 9, 1906 |
| MUNN, MORTIMER ADAM. 706 Maryland Trust Bldg., Baltimore, Md. | | July 9, 1906 |
| NORCROSS, PAUL HOWES. 1623 Candler Bldg., Atlanta, Ga. | | July 9, 1906 |
| NORTHROP, ALBERT ALLEN. Asst. Engr., Board of Water Supply, New York City, West Shokan, N. Y. | | July 9, 1906 |
| OWEN, ELIJAH HUNTER. Chagrin Falls, Ohio | | June 6, 1906 |
| POTTER, JAMES ROWLAND. 418 Oak Lane, Wayne, Pa. | | June 6, 1906 |
| RAIKES, HUGH PERCIVAL. 63 Temple Row, Birmingham, England. | | June 6, 1906 |
| REEDY, OLIVER THOMAS. Livingstone, Ariz. | | June 6, 1906 |
| ROBERTS, ARTHUR EDWIN. 8 Madison Ave., Jersey City, N. J. | | April 4, 1906 |
| SAWYER, FRANCIS MURPHY. Asst. Engr., Constr., P. R. R. Co., Newport, Perry Co., Pa. | | June 6, 1906 |

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| SCHERMERHORN, RICHARD, JR. 29 Broadway, New York City | July 9, 1906 |
| SLOCUM, CURLYS LYON. Asst. Engr., Bridge Dept., N. Y., N. H. & H. R. R., Room 314, Railroad Bldg., New Haven, Conn. | Jun. Jan. 3, 1905<br>Assoc. M. July 9, 1906 |
| SNYDER, CHARLES HERMAN. City Engr., City Hall, Oswego, N. Y. | Jun. Oct. 7, 1902<br>Assoc. M. July 9, 1906 |
| STOCKMAN, LOUIS RICHARD. Asst. Engr., U. S. Geological Survey, Babb, Mont | July 9, 1906 |
| SUNDSTROM, ALFRED YNGVE. 1410 State St., Harrisburg, Pa | June 6, 1906 |
| SWICKARD, ANDREW. Asst. Mgr., Excelsior Wooden Pipe Co., 803 Monadnock Bldg., San Francisco, Cal | June 6, 1906 |
| TARR, CHARLES WINTHROP. Res. Engr., Cape May Real Estate Co., Cape May, N. J | June 6, 1906 |
| TAYLOR, HOWARD FLANDERS. 800 Brighton Ave., Kansas City, Mo. | Jun. Feb. 28, 1899<br>Assoc. M. June 6, 1906 |
| TAYLOR, ROBERT WILLIAM, JR. Asst. Engr., P. R. R. Co., Box 642, Brownsville, Pa | June 6, 1906 |
| TERRY, ALFRED HEWE. 30 Hillhouse Ave., New Haven, Conn | June 6, 1906 |
| THORN, COLUMBUS WILLIAM. Asst. Engr., Constr., P. R. R., Camden Terminal, Camden, N. J | July 9, 1906 |
| WALLING, VICTOR ROY. Supt. and Res. Engr., Cananea Consolidated Copper Co.'s Ry., Cananea, Sonora, Mexico | June 6, 1906 |
| WARE, JOHN. Div. Engr., Connellsville Div., B. & O. R. R., 314 Cedar Ave., Connellsville, Pa | July 9, 1906 |
| WHITTED, LEVI ROMULUS. Office of Superv. Archt., Treasury Dept., Washington, D. C. | Jun. Mar. 6, 1900<br>Assoc. M. July 9, 1906 |
| WINSLOW, ARTHUR ELLSWORTH. Prof., Civ. Eng., Norwich Univ., Northfield, Vt | June 6, 1906 |
| WOODLE, ALLAN SHELDON, JR. Div. Engr., B. & O. R. R. Co., Wheeling, W. Va | July 9, 1906 |
| YUILLE, NATHANIEL ALSTON. Box 71, Demopolis, Ala | June 6, 1906 |

ASSOCIATES.

| | |
|---|---|
| BOUTON, HAROLD. Cons. Engr. and Counsellor at Law, 220 Broadway, New York City. | Jun. May 2, 1899<br>Assoc. Mar. 7, 1906 |
| BROWN, JOHN GRIFFITHS. Gen. Mgr., Unit Concrete Steel Frame Co., 1414 Commonwealth Bldg., Philadelphia, Pa | July 9, 1906 |
| LEE, ROBERT HILEMAN. 1875 Cedar Ave., Cleveland, Ohio | May 2, 1906 |

ASSOCIATES (*Continued*).

| | Date of Membership. |
|---|---|
| LOBER, JOHN BAPTISTE. Pres., Vulcanite Portland Cement Co., 1230 Land Title Bldg., Philadelphia, Pa | July 9, 1906 |
| PATTON, ALFRED GAUNT. The Oaks, Fisher's Lane, Germantown, Philadelphia, Pa | Dec. 6, 1905 |
| SCHNEIDER, EDWARD JOHN. Contr. Mgr., Am. Bridge Co. of N. Y., 704 Postal Telegraph Bldg., Kansas City, Mo | July 9, 1906 |

JUNIORS.

| | |
|---|---|
| ALDERSON, WILLIAM HOWARD. 305 San Pablo Ave. (Res., 222 Eleventh St.), Oakland, Cal | Dec. 5, 1905 |
| BARTELL, MAX JOHN. 1243 Franklin St., San Francisco, Cal | May 1, 1906 |
| BINGHAM, CLARENCE ARMINGER. 102 Grove St., Elizabeth, N. J | June 5, 1906 |
| CONNER, RALPH MELVIN. Care, U. S. Reclamation Service, Minidoka, Idaho | May 1, 1906 |
| ELAM, WILLIAM EARLE. Marlin, Tex | Feb. 6, 1906 |
| FITZRANDOLPH, WILLIAM SHEPPARD. New Market, N. J. | April 3, 1906 |
| FOWLER, FREDERICK HALL. 221 Kingsley Ave., Palo Alto, Cal | April 3, 1906 |
| HOPSON, EDWARD HAROLD. Katonah, N. Y | May 1, 1906 |
| KIENLE, JOHN ASPIN. 829 Jackson St., Wilmington, Del. | April 3, 1906 |
| O'BRIEN, DANIEL BERNARD. 390 St. Nicholas Ave., New York City | April 3, 1906 |
| PETERS, JOHN MARVIN. Connellsville, Pa | May 1, 1906 |
| RATCLIFF, WALTER HARRIS. 1643 Euclid Ave., Berkeley, Cal | Feb. 6, 1906 |
| ROBERTS, VINCENT. 253 West 123d St., New York City | Mar. 6, 1906 |
| SMITH, FORD CUSHING. Care, Pittsburg Reduction Co., Massena, N. Y | April 3, 1906 |
| SNYDER, WILLIAM HENRY. Barge Canal Office, Albany, N. Y | June 5, 1906 |
| TIFFANY, NATHAN NEWTON. East Hampton, N. Y | June 5, 1906 |
| WARLOW, ADONIRAM JUDSON. 21 Elder St., Wilkes-Barre, Pa | May 1, 1906 |
| WILSON, SAMUEL. 326 Tompkins St., Olean, N. Y | April 3, 1906 |
| WRIGHT, GEORGE CREIGHTON. Engr., Turner Constr. Co., 11 Broadway, New York City | April 3, 1906 |

## RESIGNATIONS.

ASSOCIATE MEMBERS.

| | Date of Resignation. |
|---|---|
| ADAMS, ARTHUR | June 5, 1906 |

## DEATHS.

BURNS, ROBERT BRUCE. Elected Member, September 5th, 1900; died June 21st, 1906.

GORSUCH, ROBERT BENNETT. Elected Honorary Member, January 9th, 1905; died June 2d, 1906.

PAINE, CHARLES. Elected Member, December 4th, 1867; died July 4th, 1906.

POYNOR, DAVID ASHLEY. Elected Member, June 1st, 1892; died May 29th, 1906.

ROBINSON, GEORGE HENRY. Elected Member, March 7th, 1888; died July, 1906.

WISNER, GEORGE Y. Elected Member, April 5th, 1876; died July 3d, 1906.

WRIGHT, MOSES HANNIBAL. Elected Junior, January 2d, 1900; Associate Member, September 3d, 1902; died June 8th, 1906.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(May 6th to July 27th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefeuille Economique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift fur Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.

(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift fur Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.

## LIST OF ARTICLES.

**Bridge.**

New Facts about Eye-Bars.* Theodore Cooper, M. Am. Soc. C. E. (54) Vol. 56.
Areas of Waterways for Railroad Culverts and Bridges.* George H. Bremner. (4) Apr.
Economy of Steel Sheet Piling for Coffer Dams for Bridge Piers. Julian Griggs, M. Am. Soc. C. E. (14) May 5.
A Reinforced Concrete Girder Highway Bridge.* Daniel B. Luten. (13) May 10.
Three-Hinged Concrete Arch Bridge, Brookside Park, Cleveland, O.* H. F. Hackedorn. (13) May 10.
The Use of Caissons in Bridge Building with Remarks upon Compressed Air Illness. Thomas Oliver. (29) May 11.
A 122-Ft. Four-Track Plate Girder Span.* (14) May 12.
A Page Bascule Bridge at San Francisco, Cal.* (13) May 17.
Reinforced Concrete Highway Bridges on the Big Four.* (15) May 18.
Replacing the Ashtabula Viaduct.* (14) May 19.
The Pennypack Creek Concrete Arch Bridge, P. & R. Ry.* (18) May 19.
The Page Bascule Bridge on the Santa Fe Improvements in San Francisco.* (14) May 19.
Viaduct over the River Barrow.* (11) Serial beginning May 25.
The New Railway Bridge at Newcastle.* (12) Serial beginning May 25.
A New Method of Calculating Bridge Stresses by Means of End Shears.* W. T. Curtis. (4) June.
The Distribution of Loads on Stringers of Highway Bridges Carrying Electric Cars.* F. P. McKibben. (7) June.
Arch Construction of the Connecticut Ave. Bridge, Washington. (14) June 2.
The Sixth Street Viaduct at Kansas City.* (14) June 2.
New Suspension Bridge at New York. (12) June 8.
Special Details of a Long Plate-Girder Span.* (14) June 9.
A Temporary Wooden Drawbridge.* (14) June 9.
A Thirty-three Track Bridge at Chicago.* (14) June 16.
A Diagram for Bridge Laterals.* O. W. Childs, M. Am. Soc. C. E. (13) June 21.
The Progress of the Quebec Bridge. (14) June 23.
An All-Steel Open-Floor Railroad Bridge.* (14) June 23.
Empirical Formulas for Reinforced Arches.* Daniel B. Luten. (13) June 28.
The Colfax Avenue Bridge, South Bend.* (14) June 30.
Reinforced Concrete Bridge on East Washington Street, Indianapolis, Ind.* D. B. Luten. (60) July.
The Rondout Viaduct on the West Shore Railroad.* (14) July 14.
Note sur les Résultats des Epreuves des Tabliers Métalliques de la Ligne de Quillan a Rivesaltes. M. Garau. (43) 1er Trimestre, 1906.
Ponts Suspendus et Ponts en Arc. E. Lebert. (43) 1er Trimestre, 1906.

*Illustrated.

**Bridge—(Continued).**

Arcs a Deux Rotules et Arcs Encastrés.* L. Descans. (30) June.
Beiträge zur Bewegungslehre der Ebenen Statisch Bestimmten Fachwerksträger.* H. Schütz. (81) Pts. 2-3, 1906.
Neuere Eisenbetonbrücken, ausgeführt von der Firma Ed. Züblin in Strassburg, i. E.* H. Schürch. (78) May.
Eisenbetonbrücken mit Versenkter Fahrbahn.* S. Zipkes. (78) June.
Die Beton-Eisen-Brücke Chauderon-Montbenon in Lausanne.* J. Melan. (53) June 1.
Beitrag zur Theorie des Günstigsten Trägerhöhe des Parallelträgers. F. Gebauer. (53) Serial beginning June 29.
Die Bewegungseinrichtungen der Neuen Eisenbahnbrücke über den Nordsee-Kanal bei Velsen.* J. J. W. van Loenen-Martinet and F. C. Dufour. (48) June 30.
Die Herrenbrücke bei Lübeck.* C. Buzeman. (48) July 14.

**Electrical.**

The Effect of Impurities on the Electrical Conductivity of Copper.* Lawrence Addicks. (56) Vol. 36.
Crane Motors and Controllers.* Claude W. Hill. (77) Apr.
The Telephone System of To-day. C. J. H. Woodbury. (2) Apr.
A New Single-Phase Commutator Motor.* (77) Apr.
Recent Advances in Wireless Telegraphy.* J. Erskine-Murray. (77) Apr.
Two New Electrolytic Meters.* S. H. Holden. (77) Apr.
Secondary Cells: Their Deterioration and the Causes.* G. D. Aspinall Parr. (77) Apr.
New Iron-Cored Instruments for Alternate-Current Working.* W. E. Sumpner. (77) Apr.
Note on the Use of the Bolometer as a Detector of Electric Waves.* Lieutenant C. Tissot. (77) Apr.
The Saint-Denis Electricity Works.* (73) Apr. 27.
Massie Wireless Telegraph System.* (27) Apr. 28.
Electric Power for Clay Plants from an Engineer's Point of View. Victor C. Vance. (Paper read before the National Brick Mfrs. Assoc.) (76) Serial beginning May.
Measurement of Temperature by Electrical Means.* Edwin F. Northrup. (42) May.
Notes on the Lighting of Churches.* Edwin R. Weeks. (42) May.
The Ferranti Works.* (73) Serial beginning May 4.
Electricity at the New York Hippodrome.* (27) May 5.
The Distribution of Illumination in the Neighborhood of Two Lamps. J. R. Benton. (27) May 5.
Electrolysis: General Electrical and Lightning Protection.* H. W. Spang. (24) May 7.
A New Insulating Compound. (13) May 10.
Causes and Prevention of Faults on Direct-Current Networks.* F. Fernie. (73) May 11.
Wireless Telegraphy.* Reginald A. Fessenden. (26) Serial beginning May 11.
Electricity Supply in Stoke Newington.* (26) May 11.
The Design of Electric Generators. The Use of Comparative Formulæ in the Mechanical Design of Electric Generators. W. O. Horsnaill. (11) May 11.
The Calculation of Polyphase Induction Motor Windings. F. T. Chapman. (73) May 18.
Mechanical Design of Commutators for Direct-Current Generators. R. Livingstone. (73) Serial beginning May 18.
Electrical and Mechanical Equipment of the New Engineers' Club Building, New York.* (27) May 19.
Refuse Destructor Combined with Electric Light Plant at Westmount, P. Q.* (13) May 24.
The Board of Trade Electrical Standards Laboratory.* (11) May 25.
The Lancashire Electric Power Scheme.* (26) Serial beginning May 25.
The Classification of Alternate-Current Motors.* V. A. Fynn. (73) Serial beginning May 25.
On Directed Wireless Telegraphy.* F. Braun. (Translation.) (73) Serial beginning May 25.
Plant of the Pike's Peak Hydro-Electric Company.* (27) May 26.
Synchronous Converters Versus Motor Generators. Clarence P. Fowler. (27) May 26.
Comparison of Two- and Three-Phase Motors.* Bradley McCormick. (42) June.
Heat Tests on Alternators.* Sebastiaan Senstius. (42) June.
Direct-Current Motor Design as Influenced by the Use of the Inter-Pole.* C. H. Bedell. (42) June.
The Self-Synchronizing of Alternators. Morgan Brooks and M. K. Akers. (42) June.

*Illustrated.

**Electrical—(Continued).**

Some Experiences with Lightning and Static Strains on a 33 000-Volt Transmission System.* Farley Osgocd. (42) June.
Methods of Testing Protective Apparatus.* E. E. F. Creighton. (42) June.
Protective Apparatus for Lightning and Static Strains.* H. C. Wirt. (42) June.
The Greenwich Electricity Supply Station.* (12) June 1.
Electric Lighting at Summer Resorts on the Atlantic Coast.* (27) June 2.
The Springfield, Ohio, Central Station.* (27) June 2.
Oil-Engine Driven Electric Lighting Plant at Camden, N. J.* H. B. Sweet. (27) June 2.
Some Points in Illumination.* Cole Tay. (27) June 2.
Continuous Current Motors.* J. W. Burleigh. (26) June 8.
A Modified Repulsion Motor.* F. Punga. (Abstract from *Elektrotechnische Zeitschrift.*) (26) June 8.
Electric Hoisting at the Noel-Sart-Culpart Collieries.* Alfred Gradenwitz. (16) June 9.
How to Make a Small Electric Plant Pay.* D. F. Mager. (Paper read before the Natl. Electric Light Assoc.) (27) June 9.
Series Parallel Armature Windings with Equipotential Connections. Prof. E. Arnold. (73) Serial beginning June 15; (27) Serial beginning July 14.
The New Telephone Trunk Exchange in Birmingham.* (73) June 15.
The Brighton Corporation's New Electricity Works.* (73) Serial beginning June 15.
The Gillingham Electricity Undertaking.* (26) June 15.
Some Physiological Factors in Illumination and Photometry.* Louis Bell. (Paper read before the Illuminating Eng. Soc.) (27) June 16.
Automatic Voltage Regulators.* C. W. Stone. (Paper read before the Natl. Electric Light Assoc.) (27) June 16.
A New Induction Watt-Hour Meter.* G. Faccioli. (27) June 16.
Hydro-Electric Plant at Albany, Ga.* R. W. Hutchinson, Jr. (27) June 16.
The Spherical Reduction Factor of Tantalum Lamps.* Dr. Clayton H. Sharp. (27) June 16.
The Testing of Incandescent Electric Lamps. Preston S. Millar. (27) June 16.
Cold Galvanizing. The Process and Apparatus Employed by the U. S. Electro Galvanizing Company.* (20) June 21.
Winnipeg, Manitoba, 60 000-Volt Hydro-Electric Plant.* V. D. Moody. (27) June 23.
The Central Power Plant of the Oliver Estate, Pittsburg, Pa.* (14) June 23.
Alternating-Current Magnets.* D. L. Lindquist. (27) June 23.
Control of the Direction of Electric Waves.* William Marconi. (Paper read before the Royal Soc.) (19) June 23.
Stanley's System of Transmitting and Utilizing Low-Frequency Currents. (19) June 30.
The Sale and Measurement of Electric Power.* S. B. Storer. (Paper read before the N. Y. State St. Ry. Convention.) (17) June 30.
Simple Circle Diagram of the Single-Phase Induction Motor.* A. S. McAllister. (27) June 30.
Measurement of Feeble High-Frequency Currents.* Bela Gati. (27) June 30.
Transformer Efficiency of Telephonic Induction Coils, as Related to Long Distance Transmission.* D. MacL. Therrell. (27) June 30.
Submarine Cables, their Construction, Laying and Repair.* H. C. Specht. (58) July.
High-Tension Transmission Line at Syracuse, N. Y.* (72) July.
Electric Power and Lighting Installation; Great Western Railway. Electrification of the Hammersmith and City Joint Railway.* (21) July.
Repairing Dynamo-Electric Machinery.* Norman G. Meade. (64) July.
Interference in Wireless Telegraphy and the International Telegraph Conference.* R. A. Fessenden. (26) Serial beginning July 6.
A Note on the Theory of Directive Antennae or Unsymmetrical Hertzian Oscillators.* J. A. Fleming. (Paper read before the Royal Soc.) (73) July 6.
New Rochelle Station of the Westchester Lighting Company.* (27) July 7.
Oiling Systems for Electric Engines.* W. H. Wakeman. (27) July 7.
A New Zinc-Lead Accumulator. (26) July 13.
The Electro-Chemical Problem of the Fixation of Nitrogen. Prof. Philippe A. Guye. (Abstract of paper read before the Soc. of Chemical Industry.) (73) July 13.
On the Oxidation of Atmospheric Nitrogen in Electric Arcs.* Prof. Kr. Birkeland. (Paper read before the Faraday Soc.) (73) July 13.
A 52 000 Horse-Power English Plant.* (27) July 14.
100 000-Volt Experimental Transmission Line.* K. Wernicke. (27) July 14.
A Model Turbine Power Station. The New Turbine Plant Built by the Baltimore Electric Power Company.* (14) July 21.
Polyphase Magnets.* D. L. Lindquist. (27) July 21.
Commonwealth Electric Company's New Station. The First Steam Turbine Electric Generating Station in Chicago.* (20) July 26.
Station Hydro-Electrique sur le Brembo, à Zogno (Haute-Italie).* Frank Perkins. (33) Apr. 28.

*Illustrated.

**Electrical—(Continued).**

Les Installations Electriques des Papeteries de la Région d'Aunonay (Ardèche).* E. J. Brunswick. (33) July 7.
Das Elektrizitätswerk Wangen an der Aare.* K. Meyer. (48) Serial beginning May 12.
Die Sillwerke bei Innsbruck.* Josef Riehl and others. (48) Serial beginning May 19.
Fortschritte auf dem Gebiete der Funkentelegraphie.* Otto Nairz. (82) Serial beginning June 26.

**Marine.**

A New Graving Dock at Nagasaki, Japan.* Naoji Shiraishi, M. Am. Soc. C. E. (54) Vol. 56.
The Steam-Turbine.* Hon. Charles Algernon Parsons and George Gerald Stoney. (63) Vol. 163.
Epochs in Marine Engineering. George W. Melville, Rear-Admiral, U. S. N. (55) Vol. 26.
The Present Status of the Turbine as Applied to Marine Work. Herbert C. Sadler. (1) Mar.
Ship-Model Experimental Tank at the Clydebank Shipyard.* (11) Apr. 27.
Notes on the Freeboard Rules.* J. Foster King. (Paper read before the Inst. of Naval Archts.) (11) Apr. 27.
Standardisation of Naval Machinery.* (11) Serial beginning May 4.
Submarine Signalling by Means of Sound.* J. B. Millet. (29) May 4.
Steam Yachts: Some Comparisons.* J. R. Barnett. (Paper read before the Inst. of Naval Archts.) (11) May 4.
Vickers' Appliances for Preserving and Lubricating Tail-Shafts.* (11) May 4.
The Japanese Battleship *Katori.** (12) May 11; (11) May 11.
The Stability of Submarines.* *Sir* William H. White. (Paper read before the Royal Society. (11) May 25.
The Overhead Wire Cableway Applied to Shipbuilding.* J. L. Twaddell. (Paper read before the Inst. of Naval Archts.) (47) May 26.
Water-Tube Boilers for Marine Service.* William Ledyard Cathcart. (7) June.
The New British Battleship *Dreadnought.* (10) June.
Ships and Ports. W. H. Wheeler. (12) Serial beginning June 8.
Oil-Tight Work in Ships of Light Construction.* Herbert Rowell. (Paper read before the Inst. of Naval Archts.) (11) June 15.
Gas Engines for Ship Propulsion.* J. E. Thornycroft. (Paper read before the Inst. of Naval Archts.) (19) Serial beginning June 16.
Modern Warships. *Sir* William White. (29) June 29.
Submarine Versus Submersible Boats. Simon Lake. (12) June 29.
Steam Trials of H. M. Armoured Cruiser *Cochrane.* (11) July 13.
Transports par Cables Aériens dans les Chantiers de Constructions Navales.* L. Piaud. (33) July 7.
Der Truppentransportdampfer *Borussia.** (48) June 23.
Der Doppelschraubendampfer *Kaiserin Auguste Victoria.** W. Kaemmerer. (48) July 7.

**Mechanical.**

Test of a Three-Stage, Direct-Connected Centrifugal Pumping Unit.* Philip E. Harroun, M. Am. Soc. C. E. (54) Vol. 56.
Efficiency of Internal-Combustion Engines.* (Final report of a Committee of the Inst. of Civ. Engrs.) (63) Vol. 163.
The Steam-Turbine.* Hon. Charles Algernon Parsons and George Gerald Stoney. (63) Vol. 163.
The Mechanical Handling of Hot Coke.* George Frederick Zimmer. (63) Vol. 163.
Storage and Shipment of Iron Ore at Almeria.* John Ernest Harrison. (63) Vol. 163.
A Machine for Drawing Coke from Bee-Hive Ovens.* George T. Wickes. (56) Vol. 36.
Notes on the Physical Action of the Blast-Furnace.* J. E. Johnson, Jr. (56) Vol. 36.
Some Types of Centrifugal Pumps.* Wm. O. Webber. (55) Vol. 26.
Steam Actuated Valve Gear.* W. H. Collins. (55) Vol. 26.
The Forcing Capacity of Fire Tube Boilers. F. W. Dean. (55) Vol. 26.
Pressures and Temperatures in Free Expansion. A. Borsody and R. Campbell Cairncross.* (55) Vol. 26.
The Bursting of Four-Foot Fly-Wheels.* Charles H. Benjamin. (55) Vol. 26.
An Indicating Steam Meter.* C. E. Sargent. (55) Vol. 26.
Staybolts, Braces and Flat Surfaces. A Discussion of Various Rules and Formulæ. R. S. Hale. (55) Vol. 26.
Losses in Non-Condensing Engines.* James B. Stanwood. (55) Vol. 26.
Centrifugal Fans.* August J. Bowie, Jr. (55) Vol. 26.
A Bad Case of Discharge of Water with Steam from Water-Tube Boilers. Cause and Remedies.* A. Bement. (55) Vol. 26.

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A Twist Drill Dynamometer.* William W. Bird and Howard P. Fairfield.* (55) Vol. 26.
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More Exact Methods for Determining the Efficiency of Steam Generating Apparatus. A. Bement. (55) Vol. 26.
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Condensers for Steam Turbines.* George I. Rockwood. (55) Vol. 26.
Standard Unit of Refrigeration.* F. E. Matthews. (55) Vol. 26.
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Belt Creep.* Wm. W. Bird. (55) Vol. 26.
The Transfer of Heat at High Temperatures.* Frank C. Wagner. (55) Vol. 26.
Performance of a Superheater.* A. Bement. (55) Vol. 26.
Notes on Efficiency of Steam Generating Apparatus.* A. Bement. (55) Vol. 26.
The Microstructure and Frictional Characteristics in Bearing Metals.* Melvin Price. (55) Vol. 26.
Smoke and its Abatement. Chas. H. Benjamin. (55) Vol. 26.
Continuous Measuring and Mixing of Crushed or Powdered Materials in Accurate Proportions.* E. N. Trump. (55) Vol. 26.
The Power Plant of the Tall Office Building. A Comparison between Compound and Four-Valve Simple Engines Running Non-Condensing.* S. H. Bunnell. (55) Vol. 26.
Notes on Heads of Machine Screws.* H. G. Riest. (55) Vol. 26.
Gas-Producer Plants.* Samuel S. Wyer. (56) Vol. 36.
The Manufacture and Characteristics of Wrought-Iron.* James P. Roe. (56) Vol. 36.
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Worm Contact.* Robert A. Bruce. (75) Feb.
Elevating and Conveying Machinery.* S. F. Joor. (4) Apr.
Forging Presses.* A. J. Capron. (Paper read before the Inst. of Cleveland Engrs.) (12) Apr. 27.
The Efficiency of Surface Condensers.* R. L. Weighton. (Paper read before the Inst. of Naval Archts. (12) Apr. 27; (47) May 12; abstract (14) May 19.
Construction and Use of Chains. (47) Apr. 28.
The Rationale of Rock Crushing. O. H. Howarth. (45) May.
The Marcke-Lez-Courtrai Roofing Tile Works, Marcke-Lez-Courtrai, Belgium. (Abstract from *La Ceramique.*) (76) May.
The Various Stages of Burning Clay Goods. John J. Turner. (From *Brick & Pottery Trades Journal,* England.) (76) Serial beginning May.
A New Pulverizer for Cement, Limestone, Sand, Coal, etc.* Richard K. Meade. (67) May.
Briquetting of Brown Coal. K. A. Muellenhoff. (58) May.
Standardisation of Naval Machinery.* (11) Serial beginning May 4.
The Old and the New Works of the Coventry Corporation Gas Department.* (66) May 8.
Concrete Mixing Machinery.* (46) May 12.
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Gas Producers for Power Purposes.* O. Nagel. (13) May 17.
A Heavy Duty Gas Installation in the Carnegie Technical Schools' Plant, Pittsburgh, Pa.* (20) May 17.
Chimneys and Flues.* Herbert Porter. (Abstract of article in *Journal* of Soc. of Chemical Industry.) (16) May 19.
Elevator Safeties at the Hotel Belmont.* (14) May 19.
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The Use of Producer Gas for Power Generation. Godfrey S. M. Tait. (14) May 19.
Problems in Burning Portland Cement with Long Rotary Kilns.* C. Ellis. (13) May 24.
Cast Iron in the Foundry. Percy Longmuir. (Abstract of paper read before the West of Scotland Iron and Steel Inst.) (22) May 25; (47) June 2.
Controlling Clayworking Operations. W. D. Richardson. (76) Serial beginning June.
Producer Gas and Gas Producers.* Samuel S. Wyer. (76) June.
Some High-Pressure Steam Pipe Details.* James Acton Miller. (10) June.
Cement Block Manufacture. S. B. Newberry. (Paper read before the Nat. Assoc. of Cement Users.) (60) June.
Compressed Air. Its Production, Transmission and Application. Lucius I. Wightman. (58) June.
Coke and Ore Bins.* E. W. Pittman. (58) June.
Some Practical Experiences with Steam Turbines. C. E. Stanton. (Paper read before the Iowa Elec. Assoc.) (19) June 2.

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On Some Methods for Starting Explosion Engines.* E. Butler. (47) Serial beginning June 2.
An Improved Pneumatic Tube System.* (14) June 2.
A New Method of Pumping Heavy Crude Oil or other Thick Viscous Fluid.* John D. Isaacs. (13) June 7; (15) June 8.
A Visit to German Steel Works and Rolling Mills. Henry Crowe. (Abstract of a paper read before the Cleveland Inst. of Engrs.) (11) June 8.
Suction Gas Producers. (16) June 9.
Heating and Ventilating Plant of the Indianapolis Post Office and Custom House.* (14) June 9.
The Past and Present of the Hull Works of the British Gaslight Company.* (66) Serial beginning June 12.
Foundry Tests of Coke. Richard Moldenke. (Paper read before Amer. Foundrymen's Convention.) (62) June 14.
Electrolysis of Gas Mains. M. R. Bump. (Paper read before the Western Gas Assoc.) (83) June 15; (66) July 17; (24) July 2.
Capacity of Water Gas Sets. Rollin Norris. (Paper read before the Western Gas Assoc.) (83) June 15; (24) July 9.
The R. A. S. Trials of Suction-Gas Plants.* (11) Serial beginning June 15; (12) Serial beginning June 15.
Air Compressors.* (12) Sup. June 15.
Explosion of Gaseous Mixtures, and the Specific Heat of the Products.* B. Hopkinson. (11) June 15.
Handling Spoil from City Tunnel Workings.* (14) June 16.
The Formation of Rings in Cement Kilns. Carleton Ellis. (14) June 16.
The Present Status of the Steam Turbine. (Report of a Committee of the National Electric Light Assoc.) (14) June 16.
Protection of Service Pipes. R. C. Congdon. (Paper read before the Ohio Gas Light Assoc.) (24) June 18; (66) July 10; (83) June 1.
Electrical Motive Power in Gas-Works.* (66) June 19.
Some Incandescent Acetylene Burners: Their Behaviour and Illuminating Power. F. H. Leeds. (66) June 19.
A New Fine Grinding Machine for Cement Mills.* Richard K. Meade. (13) June 21.
The Gleason Bevel Gear Generator.* (20) June 21.
Manufacture of Soil Pipes and Fittings. T. J. Best. (Paper read before the Amer. Foundrymen's Assoc.) (62) June 21; (20) June 28.
Steam Turbines.* Sydney W. Baynes. (Abstract of paper read before the Incorporated Municipal Electrical Assoc.) (73) June 22.
Great Boulder Proprietary Gold Mine. Description of the Ore Reduction Plant and Process of Reduction.* Robert Allen. (From the *Monthly Journal of the Chamber of Mines of Western Australia.*) (68) Serial beginning June 23.
Proportions and Equipment of a Light Machine Shop.* Edward H. McClintock. (47) June 23.
Efficiency of Steam Plant.* Walter A. Vignoles. (Paper read before the Incorporated Mun. Elec. Assoc.) (47) June 23; (73) July 6.
The Retorting or Carbonization of Coal.* Thomas Glover. (Paper read before the Inst. of Gas Engrs.) (66) June 26; (83) July 16.
Live Steam Heated Feed Water—Its Effect on the Output and Efficiency of Steam Boilers.* G. Wilkinson. (Paper read before the Incorporated Mun. Elec. Assoc.) (73) June 29.
Fiddes-Aldridge Stoking Machine at Wavetree Works, Liverpool.* Edward Allen. (Paper read before the Inst. of Gas Engrs.) (66) June 29.
Legal Relations Existing Between Road Authorities and Gas Undertakings.* F. T. Cotton. (Paper read before the Inst. of Gas Engrs.) (66) June 29.
The Rateau Exhaust-Steam Regeneration and Utilisation Plant.* (11) June 29.
An Electrical Measuring Machine for Engineering Gauges and other Bodies.* P. E. Shaw. (Abstract from the Philosophical Transactions of the Royal Soc.) (11) June 29.
The Vertical Retort from a Practical Point of View. Ernest Korting. (Paper read before the Inst. of Gas Engrs.) (66) June 29; (24) July 9; (83) July 16.
Notes on the Argand Burner.* Charles Carpenter. (Paper read before the Inst. of Gas Engrs.) (66) June 29.
Power Required by Machine Tools.* G. M. Campbell. (Abstract of a paper read before the Engrs. Soc. of Western Philadelphia.) (47) June 30.
Alcohol Fuel for Explosion Engines.* Karl Fehrmann. (Paper read before the German Automobile Tech. Assoc.) (47) June 30.
Theory and Practice of Lubrication. J. W. G. Brooker. (Abstract of a paper read before the Auto-Cycle Club.) (47) June 30.
A Model New Abbattoir in New York City.* (14) June 30.
Ransom Coal-Storage Plant.* (45) July.
Some Engineering Paradoxes. (10) July.
Earlier and Modern Wet-Grinding Machines and Practice.* H. F. Noyes. (9) July.

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High-Lift Turbine Pumps. Their Design and Efficiency. R. J. Durley. (9) July.
The Practical Aspects of Entropy. Dr. Jos. H. Hart. (9) July.
Mixtures of Magnesite and Zettlitz Kaolin. Dr. Reinhold Reike; tr. by Harrison Everett. (76) Serial beginning July.
Rational Methods of Gas-Engine Powering. Sanford A. Moss. (64) July.
Engine Economy as Affected by Unequal Cut-Off.* Thomas Hall. (64) July.
Remarkable Efficiencies in Small Engines using Superheated Steam. R. E. Mathot. (64) July.
Economy Test of a Skinner Engine.* (64) July.
Some Facts about Steam Pipe Lines.* Walter E. Dickson. (64) July.
Gas Driven Electric Power System. As Exemplified in the Warren & Jamestown Railway System.* J. R. Bibbin. (58) July.
Carbonisation. W. E. Hartman. (Paper read before the Western Gas Assoc.) (83) July 2; (66) July 17; (24) July 9.
Principles of Illumination from the Standpoint of the Gas Engineer.* Van Rensselaer Lansingh. (Paper read before the Western Gas Assoc.) (83) Serial beginning July 2; (24) July 16.
Earthquake Damage to San Francisco Gas Plants.* F. H. Shelton. (83) July 2.
The Dessau Vertical Retort-Settings.* Dr. J. Bueb. (Paper read before the German Assoc. of Gas and Water Engrs.) (66) July 3.
Influence of Gasholders on Quality of Gas. Payet. (Tr. of a paper read before the Soc. Tech. du Gaz en France.) (66) July 3.
Air Furnace Practice. A Comparison of Designs and Methods of Working.* Ralph H. West. (Paper read before the Amer. Foundrymen's Assoc.) (20) July 5.
Fuel Economy.* J. Henry Hallberg. (Abstract of a paper read before the National Elec. Light Assoc.) (14) July 7.
Mechanical Equipment of the New Residence of Senator Clark in New York.* (14) July 7.
A Large Shale Brick Factory in Eastern Illinois.* (14) July 7.
Burning Low-Grade Fuel. Boiler Firing with Coal Containing a Large Percentage of Ash, Slate and other Incombustible Matter. James F. Hobart. (27) July 7.
First Electric Motor-Driven Rail Mill.* (62) July 7.
Liquid Versus Coal Fuel.* W. N. Best. (19) July 7.
Details Entering into the Calculation and Construction of Wellman's Polar Airship.* (19) July 7.
Wellman's Airship for his North Polar Expedition.* (46) July 7.
The Utilization of Tar in a Water Gas Apparatus.* Geo. H. Waring. (Paper read before the Western Gas Assoc.) (24) July 9; (83) June 15.
Firing of Retort Benches by Battery Producers. Fred. Bredel. (Paper read before the Western Gas Assoc.) (24) Serial beginning July 9; (83) July 2.
Measurement of Friction in Gas-Engines. A. H. Burnand. (11) July 13.
Steam Turbine Station of Baltimore Electric Power Company.* J. R. Bibbins. (27) July 14.
The Growth of the Pumping Station. Charles A. Hague. (Paper read before the Amer. Water Works Assoc.) (14) July 14.
Refrigeration System of the Model New Abattaoir in New York City.* (14) July 14.
New Sand-Lime Brick Plant at South River, N. J.* (14) July 14.
The Industrial Application of Chimney Gases. (62) July 14.
Live Steam-Heated Feed Water. G. Wilkinson. (Paper read before the Municipal Elec. Assoc.) (47) Serial beginning July 14.
Water Gas Practice.* D. G. Fisher. (Paper read before the Western Gas Assoc.) (83) July 16; (24) Serial beginning July 23.
Experiments on the Removal of Tar from Water Gas.* E. H. Earnshaw. (Paper read before the Western Gas Assoc.) (83) July 16.
Report on the Kramers and Aarts Water-Gas Plant at Zevenbergen Gas-Works.* Payet. (Abstract of paper read before the Soc. Tech. du Gaz.) (66) July 17.
A Model Turbine Power Station. The New Turbine Plant Built by the Baltimore Electric Power Company.* (14) July 21.
Power Plant of the New Abattoir in New York City.* (14) July 21.
Commonwealth Electric Company's New Station. The First Steam Turbine Electric Generating Station in Chicago.* (20) July 26.
Recent Extensions of the Employment of Compressed Air. Frank Richards. (13) July 26.
La Cuisson du Ciment Portland au Point de Vue Thermo-Chimique. (Tr. fr. *Ciment.*) (84) May.
Le Ravitaillement en mer des Navires au Moyen de Transporteurs Aériens.* A. Bidault des Chaumes. (33) May 19.
Mode de Réglage Cycles et Construction des Moteurs a Combustion Interne. R. E. Mathot. (Paper presented to the *Congres international des mines, de la metallurgie et de la mecanique* at the Liege Exposition.) (37) May 31.

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Eine Moderne Giessereianlage.* Gg. Rietkötter. (50) Serial beginning May 1.
Zur Thermochemie des Portlandzementbrandes. (80) May 5.
Vergleich des Berechneten und Wirklichen Brennstoffverbrauches in Drehrohrofen. Henry S. Spackman. (Abstract of paper read before the Americanischen Portlandzementerzeuger.) (80) May 12.
Die Gasrohrschweissöfen.* Anton Bousse. (50) Serial beginning May 15.
Zur Frage der Bewegung und Lagerung von Hüttenrohstoffen.* M. Buhle. (Paper read before the Verein deutscher Eisenhüttenleute.) (50) Serial beginning June 1.
Elektrischer Antrieb von Triowalzwerken.* Ed. Hofmann. (50) June 1.
Neuere Erfahrungen in Feuerungsbetrieben.* A. Blezinger. (Paper read before the Eisenhütte Düsseldorf.) (50) June 15.
Vergleich der Druck- und Ueberdruck-Dampfturbinen-Donát Bánki. (48) June 16.
Die Beanspruchung auf Verdrehen an einer Uebergangstelle mit Scharfer Abrundung.* A. Föppl. (48) June 30.
Ueber den Inneren Aufbau Gehärteten und Angelassenen Werkzeugstahls.* E. Heyn and O. Bauer. (50) July 1.
Versuche an der Kohlenumladeanlage in Breslau.* Kaemmerer. (48) July 7.
Der Nutzen des Dampfmantels nach Neueren Versuchen.* A. Bantlin. (48) July 7.
Neuere Hebezeuge.* Georg von Hanffstengel. (82) Serial beginning July 7.
Welche Neueren Erfahrungen Liegen über Drehrohröfen vor?* C. W. Timm. (Paper read before the Verein deutscher Portlandzementfabrikanten.) (80) July 12.
Die Knicksicherheit der Stege von Walzwerkprofilen.* A. Sommerfeld. (48) July 14.

**Metallurgical.**

The Francke-Tina Process for the Reduction of Silver Ores, as carried on at Cayllorna, Peru.* Alfred Fox. (63) Vol. 163.
Notes on the Physical Action of the Blast-Furnace.* J. E. Johnson, Jr. (56) Vol. 36.
An Automatic Stock-Line Recorder for Iron Blast-Furnaces.* J. E. Johnson, Jr. (56) Vol. 36.
Improved Method of Slag-Treatment at Argo.* Harold V. Pearce. (56) Vol. 36.
Kernel-Roasting.* Herman Poole. (56) Vol. 36.
Tin-Mining and Smelting at Santa Barbara, Guanajuato, Mexico.* (56) Vol. 36.
Cyaniding Silver-Gold Ores of the Palmarejo Mine, Chihuahua, Mexico. T. H. Oxnam. (56) Vol. 36.
The Application of Dry-Air Blast to the Manufacture of Iron—Supplementary Data. James Gayley. (56) Vol. 36.
The Importance of Fine-Grinding in the Cyanide-Treatment of Gold and Silver Ores. Frederick C. Brown. (56) Vol. 36.
The Constitution of Mattes Produced in Copper-Smelting. Allan Gibb and R. C. Philp. (56) Vol. 36.
Seventh Report to the Alloys Research Committee: On the Properties of a Series of Iron-Nickel-Manganese-Carbon Alloys.* Dr. H. C. H. Carpenter, R. A. Hadfield, and Percy Longmuir. (75) Dec., 1905.
A Digest of the Criticisms of Gayley's Dry Air Blast Process. F. A. Willcox. (22) May 11.
The Direct Production of Copper.* (11) May 18.
Black Sand of the Pacific Coast. Robert H. Richards. (7) June.
A Wet Silver Mill at a Montana Mine—Construction of Mill—Machinery Used. Method of Treating the Ore.* Robert B. Brinsmade. (45) June.
Electrical Steel Melting at Disston Plant. The Pioneer American Electric Steel Furnace.* (20) June 7.
The Relative Corrosion of Wrought-Iron and Steel. Henry M. Howe. (Paper read before the Amer. Soc. for Testing Materials.) (13) June 28; (20) June 28; (47) July 14; (22) July 13.
The Beneficial Effects of Adding High Grade Ferro-Silicon to Cast-Iron. Alexander E. Outerbridge, Jr. (Paper read before the Amer. Foundrymen's Assoc.) (22) June 29; (47) July 7.
Malleable Cast Iron.* G. A. Akerlind. (Paper read before the Scandinavian Tech. Soc.) (47) June 30; (15) June 8.
The Stamp Mill and Cyanide Plant of the Combination Mines Company at Goldfield, Nevada.* Mark R. Lamb. (16) June 30.
Segregation in Steel Ingots. Its Relation to Plate Specifications.* (Paper read before the Amer. Soc. for Testing Materials.) (20) July 5.
Electric Smelting of Iron Ore.* (16) July 7.
Gas Cleaner for Blast Furnace Gas.* Patrick Meehan. (62) July 7.
Specifications for Foundry Pig Irons. W. B. Parker. (Paper read before the Brit. Foundrymen's Assoc.) (47) July 7; (72) July 21.
The Daly-West Mill, Park City, Utah.* (16) July 14.
The Blast Furnace Plant of the Federal Furnace Company.* (20) July 19.

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The Northern Iron Company's Blast Furnace.* J. H. Granbery. (16) July 21.
Ueber die Nutzanwendung der Metallographie in der Eisenindustrie.* E. Heyn. (Paper read before the Verein deutscher Eisenhüttenleute.) (50) May 15.
Moderner Umbau eines Hochofens in Südrussland.* Paul Thomas. (50) May 15.
Zur Bestimmung des Schwefels im Eisen mit Besonderer Berücksichtigung des Maassanalytischen Verfahrens.* C. Reinhardt. (50) July 1.
Vorgänge beim Stahlschmelzen.* A. Ruhfus. (50) July 1.

**Military.**

The Manufacture of Cartridge-Cases for Quick-Firing Guns.* Colonel Leandro Cubillo and Archibald P. Head. (75) Dec., 1905.
Primers and Fuzes for Cannon.* Major Ormond M. Lissak. (From the *Journal* of the United States Artillery.) (19) Serial beginning June 16.

**Mining.**

The Commercial Value of Coal-Mine Sampling. Marius R. Campbell. (56) Vol. 36.
Anthracite-Washeries.* George W. Harris. (56) Vol. 36.
Geological Mine-Maps and Sections.* D. W. Brunton. (56) Vol. 36.
Tin-Mining and Smelting at Santa Barbara, Guanajuato, Mexico.* (56) Vol. 36.
Notes on the Detection and Estimation of Inflammable Gases in Mines by means of Flame-Caps. Charles Latham. (59) Vol. 28, Pt. 4.
Non-Rotating Wire-Ropes, and Tests of Wire-Rope Attachments. Ernest King. (59) Vol. 28, Pt. 4.
Shaft Timbers.* Thomas Varcoe. (68) Serial beginning May 12.
Hydraulic Mining in California.* J. P. Hutchins. (16) May 19.
Mine Explosions. J. T. Beard. (16) May 19.
The Robinson Gold-Dredger.* (11) May 25.
Mine No. 2, St. Louis & O'Fallon Coal Co. A Description of the Equipment of a New Bituminous Coal Mine of Large Capacity, near Belleville, Illinois.* (45) June.
Submarine Coal Mining. Richard H. Brown. (Paper read before the Mining Soc. of Nova Scotia.) (22) June 1; (45) June.
Explosives in Coal Mines. Departmental Committee on the Use of Bobbinite. (57) Serial beginning June 1.
Some Examples of Modern Mine Ventilation.* (22) June 8.
Notes on Top and Bottom Endless Rope Haulage on Curves at Bedlington Collieries.* E. Graham. (Paper read before the National Assoc. of Colliery Managers.) (22) June 8.
Electric Hoisting at the Noel-Sart-Culpart Collieries.* Alfred Gradenwitz. (16) June 9.
Commercial Possibilities of Electric Winding for Main Shafts and Auxiliary Work. W. C. Mountain. (Abstract of paper read before the Inst. of Mining Engrs.) (22) June 15; (73) June 22.
Electrically-Driven Air-Compressors Combined with the Working of the Ingersoll-Sergeant Heading Machines and the Subsequent Working of the Busty Seam at Ouston Colliery.* A. Thompson. (Abstract of paper read before the Inst. of Mining Engrs.) (22) June 15; (73) June 22.
Considerations on Deep Mining. George Farmer. (Review of Report of the Royal Comm. on Coal Supplies.) (22) June 15.
Labor-saving Machinery in Coal Mining. F. W. Parsons. (16) June 16.
The Westinghouse Converter-Equalizing System for Variable Loads (Winding Motors, Rolling Mills, etc.) (22) June 22.
The Shamrock Rescue Apparatus at the Courrieres Collieries.* G. A. Meyer. (Paper read before the Inst. of Mining Engrs.) (68) June 23; (22) June 22.
Philippine Coal Deposits. Diamond Drilling in the Philippines and the Development of the Coal Deposits of Batan Island.* Lieut. H. L. Wigmore. (45) July.
Prospecting a Gold Placer.* (45) July.
The Latest Ore-Handling Machinery on the Great American Lakes.* Day Allen Willey. (10) July.
The "Pneumatogen" Rescue Apparatus for Mines. Richard Cremer. (22) July 6.
Mine Sanitation on the Rand. Donald Macaulay and Louis G. Irvine. (Abstract of a paper read before the Chemical, Metallurgical and Mining Soc. of South Africa.) (68) Serial beginning July 7.
Electrically-Operated Ventilating Plant in Northberg Pit, Germany.* Alfred Gradenwitz. (16) July 14.
The Daly-Judge Mine.* (16) July 21.
Le Remblayage par l'Eau.* H. Schmerber. (33) Serial beginning May 26.

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**Miscellaneous.**

The Position of the Constructing Engineer, and his Duties in Relation to Inspection and the Enforcement of Contracts. Albert J. Himes, M. Am. Soc. C. E. (54) Vol. 56.
Function of Laboratory Courses in the Curriculum of Engineering Schools. Charles Edward Lucke. (55) Vol. 26.
The Metric System Fallacy: Anti-Metric Opinions from Leading American Engineers and Manufacturers. (10) June.
Cost Keeping on Public Works. Waldo S. Coulter. (13) June 14.

**Municipal.**

The Drainage of Earth Roads.* (14) May 5.
The Municipal Asphalt Repair Plant at Pittsburg, Pa.* Charles Brossman, Jr. (13) May 31.
The Rattling Test as a Safe Method of Disclosing the Permissible Absorption of Paving Brick. Edward Orton, Jr. (Paper read before the National Brick Mfrs. Assoc.) (76) Serial beginning June.
Tests for Paving Brick. (60) June.
The Structural, Municipal and Sanitary Aspects of the Central California Catastrophe. Charles Gilman Hyde, Assoc. M. Am. Soc. C. E. (14) Serial beginning June 2.
Concrete Pavements in Chicago.* (14) June 9.
The Road Drag for Improving Earth Roads.* (Abstract of Bulletin No. 1 of the Illinois State Highway Comm.) (13) June 14.
The Development of the Test for the Cementing Value of Road Material. Allerton S. Cushman. (Paper read before the Amer. Soc. for Testing Materials.) (14) June 23.
The Proximate Composition and Physical Structure of Trinidad Asphalt. Clifford Richardson. (Paper read before the Amer. Soc. for Testing Materials.) (14) June 30.
Experiments with Tar and Oil for Roads at Jackson, Tenn.* (Abstract of Report, Office of Public Roads.) (14) June 30.
A New Use for Coal Tar: Important Information—Four Years' Results with Tar Coating Streets to Eliminate Dust. Dr. Guglifiminetti. (Tr. by Frederic Egner from the *Journal fur Gasbeleuchtung.*) (24) July 23.
Municipal Ownership in Massachusetts. Fred B. Wheeler. (24) July 23.

**Railroad.**

The Scranton Tunnel of the Lackawanna and Wyoming Valley Railroad.* George B. Francis and W. F. Dennis, Members, Am. Soc. C. E. (54) Vol. 56.
Fuel Consumption of Locomotives.* G. R. Henderson. (55) Vol. 26.
Road Tests of Brooks Passenger Locomotives.* E. A. Hitchcock. (55) Vol. 26.
Technical Considerations in Electric Railway Engineering.* F. W. Carter. (77) Apr.
Areas of Waterways for Railroad Culverts and Bridges.* George H. Bremner. (4) Apr.
A Comparative Test between a Simple and Compound Locomotive.* Harold St. Clair MacMillan and others. (Thesis submitted for degree of B. S. in Mech. Eng., Univ. of Wis.) (61) Apr. 17.
Superheated Steam on the Canadian Pacific Railway.* H. H. Vaughan. (65) Apr. 20.
Whitaker's Electric Train Tablet-Exchanger.* (11) Apr. 27.
The Electrification of the New York Central Terminus.* (12) Apr. 27.
Compound Locomotives.* G. R. Sisterson. (12) Apr. 27.
Care and Maintenance of Freight and Passenger Engines at Terminal to Give Maximum Mileage and Efficient Service. E. T. James. (65) May.
The Gasoline Car for Interurban Service.* F. W. Hild. (Paper read before the Iowa St. and Interurban Ry. Assoc.) (13) June 21; (72) May; Extracts. (15) June 1; (18) June 2; (17) May 5.
Bond and Motor Testing. R. W. Conant. (Paper read before the Iowa St. and Interurban Ry. Assoc.) (72) May.
New York Central Consolidation Locomotive.* (39) May.
Pacific Type Locomotive Southern Railway.* (39) May.
A. C.—D. C. Locomotives for the New York, New Haven and Hartford Railroad.* (39) May.
Constructing Railroads in India.* (21) Serial beginning May.
Locomotive Boiler Design.* D. Van Alstyne. (Paper read before the North-West Ry. Club.) (21) May.
Three Cylinder Compound Express Locomotives: Midland Railway.* (21) May.
The Long Island City Power Station of the Pennsylvania Railroad.* W. N. Smith and Dudley W. Walton. (26) May 4.
Brotan Locomotive Boiler with Water Tube Firebox.* (40) May 4.
The Upward Indication of the Semaphore Arm. L. R. Clausen. (Paper read before the Ry. Signal Assoc.) (40) May 4; Abstract (18) May 12; (15) May 11.

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Construction of the Gallitzin Tunnel on the Pennsylvania Railroad.* (14) May 5.
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Toledo, Port Clinton & Lakeside Electric Railway.* (40) May 11.
Processes for Car Wheel Manufacture.* (22) May 11.
New East Bottoms Yard of the Missouri Pacific at Kansas City.* (15) May 11.
Union All-Electric Interlocking at Elsmere Junction.* (15) May 11.
Relining the Allegheny Tunnel, Pennsylvania R. R.* (14) May 12.
The Reinforced Concrete Beam Culvert: An Inefficient Structure.* Daniel B. Luten. (13) May 24.
Troubles with East River Tunnels. S. D. V. Burr. (20) May 24.
Steel Flat Cars for Specially Heavy Loads.* (13) May 24.
Victoria Station.* (12) May 25.
Brakebeams and Foundation Rigging: The Requirements from the Standpoint of Safety and Emergency. Edward B. Leigh. (40) May 25.
The Pennsylvania R. R. Passenger Station in New York City.* (13) May 24; (15) May 25; (14) May 26.
Pennsylvania R. R. Extension to New York and Long Island: The Passenger Station in New York.* (40) May 25; (18) May 26.
Comparative Test of Large Locomotive Air Pumps.* (18) May 26; (40) May 18.
Co-ordinate Geometry Applied to Problems in Railroad Alignment. G. L. Bilderbeck. (14) May 26.
The St. Francois County Electric Railway.* (17) May 26.
Curving Rails by Power: Nashville, Chattanooga & St. Louis Ry. Geo. F. Blackie. (Abstract of paper read before the Eng. Assoc. of the South.) (13) May 31.
Transmission and Distribution System, Long Island R. R.* (13) June 14; (46) June 9; (17) Serial beginning June 9; (18) Serial beginning June 9; (15) June 8; (72) June.
Notes on Great Tunnels.* Lewis M. Haupt. (3) June.
Prairie Type Passenger Locomotive with Walschaert Valve Gear: Lake Shore & Michigan Southern Railway.* (25) June.
South Louisville Shops: Louisville & Nashville Railroad.* (25) Serial beginning June.
Simple Consolidation Locomotive with Walschaert Valve Gear: Pennsylvania Railroad.* (25) June.
6-Coupled Narrow Gauge Engine; Egyptian Delta Light Railways.* (21) June.
Compound Express Engines; Bavarian State Railways.* Chas. S. Lake. (21) June.
30-ton Ironstone Wagon; North-Eastern Railway.* Wilson Worsdell. (21) June.
Goods Offices, Paddington; Great Western Railway.* (21) June.
Pacific Type Passenger Locomotives.* (39) June.
New Prairie Type Locomotive: Lake Shore & Michigan Southern Ry.* (39) June.
Comparative Test of Large Locomotive Air Pumps.* (Tests made by the Lake Shore & Michigan Southern Ry. Co.) (39) June.
The Clay Slide at the Boone Viaduct, Boone, Iowa.* A. W. Merrick. (4) June.
Foreign Railway Construction in Sliding Ground.* E. E. R. Tratman. (4) June.
Roller Bearings. Thomas W. How. (Paper read before the Brit. Tramways and Light Rys. Assoc.) (72) June.
Fire Protection for Car Barns. Joseph B. Finnegan. (72) June.
The Brierley Fog-Signaling Apparatus for Railroads.* (46) June 2.
Steel Cofferdam for a Hudson River Tunnel Shaft. (14) June 2.
Latest Express Engines—South-Eastern and Chatham Railway. Charles Rous-Martin. (12) Serial beginning June 8.
Baltimore & Ohio Refrigerator Car.* (15) June 8.
Standard 80 000-lb. Box Car for the Rock Island-Frisco System.* (15) June 8; (27) Serial beginning June 9.
A Graphic Record of Train Operation.* (40) June 8.
The New Shops of the Canada Car Company, Ltd., at Montreal.* (15) June 8.
All-Electric Interlocking at Council Bluffs.* (15) June 8.
Phosphate Cars for the Atlantic Coast Line.* (15) June 8.
Car Ferry Lines of American Railroads.* R. C. Davison and B. Boardman. (15) June 8.
New Kingsland, N. J., Shops of the D., L. & W. Ry.* (18) June 9.
New Types of Goodwin Car.* (18) June 9.
Block and Interlocking Signals in the Electrical Zone of the New York Central & Hudson River R. R.* (13) June 14; (17) June 9; (18) Serial beginning June 9; (40) June 8; (15) June 29; (72) June.
Reducing the Wear of Driving-Wheel Flanges on Sharp Curves.* (13) June 14.
A Reinforced Concrete Locomotive Coaling Station of Unusual Construction on the Lehigh Valley Railroad.* W. E. Phelps. (13) June 14.
Brake Beams for 60 000, 80 000 and 100 000-lb. Freight Cars. (Report of a Committee of Master Car Builders' Assoc.) (13) June 14.

*Illustrated.

**Railroad—(Continued).**

New York Central Electric Locomotives.* Reginald Gordon. (15) June 15.
Master Car Builders' Assoc. Committee Reports.* (15) June 15, 22; (18) June 16; (13) June 21; (25) July.
Recent Development of American Passenger Locomotives.* George L. Fowler. (15) June 15.
Balanced Compound Locomotives.* H. V. Wille. (15) June 15.
Consolidation Locomotive for the New York Central Lines.* (15) June 15.
Baltimore & Ohio Railroad Motive Power.* (15) June 15; (40) June 15.
Improved Round House Facilities.* J. C. Stuart. (15) June 15.
Rolled Steel Wheels for Interurban Service.* H. S. Newton. (17) June 16.
Screw Spikes and Wooden Tie-Plates for Railway Track.* (13) June 21.
Park Royal Power Station and the Hammersmith and City Electric Railway. (26) Serial beginning June 22; (73) Serial beginning June 22.
Pennsylvania Railroad's Extension to New York and Long Island—Rotary Converter Substations of the Long Island Railroad.* (40) June 22; (18) July 14.
Standard All-Steel 60-Ft. Postal Car for the Harriman Lines.* (15) June 22.
American Railway Master Mechanics Assoc. Reports.* (15) June 22; (13) June 28; (27) June 23; (15) June 29; (18) June 23; (47) June.
The Rotary Converter Sub-Stations of the Long Island Railroad.* W. N. Smith. (17) June 23.
Track Elevation at Chicago on the Pittsburgh, Ft. Wayne & Chicago Ry.* (14) June 23; (40) June 22; (13) July 5; (15) July 6; (18) June 30.
Firebox Steel—Failures and Specifications. Max H. Wickhorst. (Abstract of paper read before the Amer. Soc. for Testing Materials.) (40) June 29; (18) July 7; (13) July 19.
Pacific Locomotive for the Southern Railway.* (15) June 29.
Gas Driven Electric Power System. As Exemplified in the Warren and Jamestown Railway System.* J. R. Bibbin. (58) July.
Testing and Inspection of Railroad Supplies. Robert Job. (3) July.
Sudbury and Harrow Road Station; Great Central Railway.* (21) July.
Baltimore & Ohio Railroad Motive Power.* (25) July.
Simple Consolidation Locomotive with Walschaert Valve Gear, Lake Shore & Michigan Southern Railway.* (25) July.
Renewing Railroad Waterways with Concrete Culverts.* C. B. Wilson and I. O. Walker. (Papers read before the Eng. Assoc. of the South.) (60) July.
Timber Creosoting Plant at Shirley, Ind. H. H. Knowlton. (Paper read before the Indiana Eng. Soc.) (60) July.
The Commerce Street Power Plant of the Milwaukee Electric Railway & Light Company.* (72) July.
St. Gotthard and Simplon Tunnel Railway Service.* (41) July.
The Signalling of the Victoria (New) Station; L., Brighton and S. C. Railway.* (21) July.
Electric Power and Lighting Installation; Great Western Railway. Electrification of the Hammersmith and City Joint Railway.* (21) July.
The Tehuantepec Railway and the Harbors at its Ocean Terminals.* (13) July 5.
A Low-Cost Concrete Culvert.* W. H. Whorley. (Paper read before the Eng. Assoc. of the South.) (13) July 5.
Big Four Reconstruction, Indianapolis to Coal Bluff.* (40) July 6.
The Pennsylvania Tunnels under the East River.* (15) Serial beginning July 6; (13) July 12.
Electric Traction Progress on the Lancashire and Yorkshire Railway.* (26) Serial beginning July 6.
The Depew Place Excavation.* (14) July 7.
The East River Tunnels for the New York City Terminus of the Pennsylvania and Long Island Railroads. (14) July 7.
The Pekin-Hankow Railway in China.* P. H. Ashmead. (13) July 12.
The Enlargement of Victoria Station.* (11) July 13.
Rebuilding the Highland Division of the New York, New Haven & Hartford.* (15) July 13.
Rack Locomotive for Manitou and Pike's Peak Railway.* (15) July 13.
Welding Locomotive Frames. R. P. C. Sanderson. (Abstract of paper read before the M. M. Assoc.) (15) July 13.
Comparative Tests of Large Locomotive Air Pumps.* (15) July 13.
Boiler Pressures.* Prof. W. F. M. Goss. (Abstract of a paper read before the Amer. Ry. Master Mechanics Assoc.) (40) July 13.
Piston Valves. E. A. Miller and others. (Discussion before the Amer. Ry. Master Mechanics Assoc.) (40) July 13.
Locomotive Tachographs.* (12) July 13.
The Construction of the East River Division of the Pennsylvania, New York and Long Island Railroad Company's Tunnels.* (14) Serial beginning July 14.
Recent de Glehn System Compound Locomotives.* (47) July 14.
The New Public Service Building of the Milwaukee Electric Railway and Light Company.* (17) July 14; (14) July 21; (72) July.

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**Railroad—(Continued).**

Electric Locomotive Tests on the Seebach-Wettingen Railway.* Frank C. Perkins. (18) July 14.
A Visit to the P., B. & W. Ry. Wilmington Shops.* (18) June 16.
A Large Railway Freight House and Warehouse at Pittsburg, Pa.* (13) July 19.
Some Recent Block Signal Systems for Electric Railways.* (13) July 19.
Mogul Locomotives for the Panama Excavation.* (15) July 20.
The Carnegie Steel Tie.* (15) July 20.
Some Essentials in a Locomotive Boiler Design.* D. Van Alstyne. (Paper read before the North-West Club.) (15) July 20.
Brake-Rigging and Uneven Wear of Brake-Shoes.* W. L. Boyer. (17) July 21.
Improvements and Operating Features of the Southwest Missouri Electric Railway.* (17) July 21.
Methods of Handling Snow on Electric Railways.* (13) July 26.
Special Commissioners' Report on Improved Railway Terminals and a New Municipal Bridge over the Mississippi River at St. Louis, Mo. (13) July 26.
The Air Power Plants for the East River Tunnels of the Pennsylvania Railroad.* (15) July 27.
Les Chemins de Fer a Crémaillère.* A. Levy-Lambert. (32) Mar.
La Poussée des Terres contre les Murs de Soutènement.* L. Malevé. (30) Apr.
Note sur la Production des Ateliers des Chemins de Fer en Amérique. Th. Laurent. (38) May.
Chauffage des Trains par la Vapeur et l'Eau Combinées, ou par la Vapeur Détendue.* H. Guerin. (33) May 12.
Note sur les Injections de Ciment Pratiquées dans le Souterrain de Limonest (Rhône) sur la Ligne de Lozanne à Givors. M. Beynet. (38) June.
Sur la Construction des Réservoirs a Haute Pression. H. Royer. (37) June.
Traction Electrique a 2 400 Volts sur la Ligne de Saint-Georges-de-Commiers à la Mure (Isere).* (33) June 2.
Le Tunnel du Simplon.* E. Lemaire. (33) Serial beginning June 23.
Lokomotiven mit Ventilsteuerung.* Metzeltin. (48) Serial beginning Apr. 28.
Die Elektrische Bergbahn Brunnen-Morschach (Schweiz).* Wolfgang Adolf Müller. (48) May 19.
Benzinelektrische Selbstfahrer im Eisenbahnbetriebe.* Jaromir Krizko. (53) June 8.
Die Bauschwierigkeiten beim Bosrucktunnel.* M. J. Blodnig. (53) June 22.

**Railroad, Street.**

Steel Rolling Stock. George Harrison Sheffield. (Abstract of paper read before the Tramways and Light Railways Assoc.) (73) Apr. 27.
Shunt- and Compound-Wound Synchronous Converters for Railway Work. W. L. Waters. (42) May.
The Electric Tramways of New Zealand.* (Abstract from *Progress.*) (72) May.
The Standard Car Body and Truck. Geo. H. Tontrup. (Paper read before the Iowa St. and Interurban Ry. Assoc.) (72) May.
The Atlantic Avenue Station of the East Boston Tunnel.* (72) May.
Car House, Shops and Shop Practices at Birmingham, Ala.* (17) May 5.
The Fremantle (Australia) Municipal Tramways.* (17) May 5.
Single-Phase Railway for the Milan Exhibition, 1906.* E. Fumero. (Abstract from *L'Elettricita.*) (73) May 11.
Alternating Current Track Circuits in the New York Subway.* J. M. Waldron. (Paper read before the Ry. Signal Assoc.) (15) May 11; (18) May 19.
Planking under Track in New Orleans.* (17) May 12.
Thermit Rail-Welding in New York City. R. F. Kelker. (17) May 12.
Recent Tunnel Construction of the Rapid Transit Railroad in Brooklyn.* (14) May 12.
Improvements of the Brooklyn Rapid Transit Company.* (40) May 18.
The New Cars of the South Side Elevated Railway, Chicago, and Their Equipment.* (17) May 19.
Automatic Signalling on the Underground Railways of London.* (11) Serial beginning May 25.
A Train Order Signal System for Electric Railways.* (13) May 31.
Electric Street Cars for City Service.* M. B. Starring and H. B. Fleming. (4) June.
The Street Railway System of Lucerne, Switzerland.* Frank Koester. (72) June.
Improvements on the Elevated and Surface Lines of the Brooklyn Rapid Transit Co.* (72) June.
New Electric Trains on the Metropolitan Railway.* (73) June 1.
Electric Locomotives on the Metropolitan Railway.* (73) June 1.
Grade Corrections in the Battery Tunnel, New York.* (14) June 2.
An Official Report on Heat Conditions in the New York Subway by Chief Engineer Geo. S. Rice. (13) June 7.
Electrolysis of Underground Pipes. (Summary of the Report of the Committee of the Amer. Gas Light Assoc.) (83) June 15.

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**Railroad, Street—(Continued).**

Handling Spoil from City Tunnel Workings.* (14) June 16.
Sale of Water-Power from the Power Company's Point of View. C. E. Parsons. (Paper read before the N. Y. State St. Ry. Convention.) (17) June 30.
New Car House and Truck Shop of the International Railway Company, Buffalo, N. Y.* (72) July.
Modern American and European Trackless Trolleys.* (41) July.
Rotary Converter Substation for Syracuse Rapid Transit Railway. (72) July.
The New Car House and Remodeled Shops of the International Railway Company, Buffalo, N. Y.* (17) July 7.
Greenwich Generating Station for London Tramways.* (17) July 7.
An Important Street Improvement with Street Railway Subway at London, England.* (13) July 12.
Rapid Transit in Chicago.* Bion J. Arnold. (Abstract of report to the Committee on Local Transportation of the Chicago City Council.) (15) July 13; (18) July 14; (13) July 19.
The 60 000-Volt Sub-Station and Transmission Line of the Syracuse Rapid Transit Company.* (17) July 14.
Whitewashing a London Tube Railway.* Albert H. Bridge. (17) July 21.
Le Métropolitain de Paris: Situation des Nouvelles Lignes Projetées et Etat des Travaux des Lignes en Cours d'Exécution.* A. Dumas. (33) Apr. 21.
Le Chemin de Fer Electrique Souterrain Nord-Sud de Paris.* A. Dumas. (33) Apr. 28.
Le Chemin de Fer Métropolitain de Paris.* (34) May.
Essai des Machines de la Station Génératrice du New-York Subway.* C. Smith. (33) June 16.

**Sanitary.**

Sewage Disposal at Manchester and Birmingham.* Leonard Parker Kinnicutt. (1) Mar.
Operation of Sewerage Works.* (Papers read before the Boston Soc. of Civ. Engrs.) (1) Apr.
System of Exhaust Steam Heating in the New Foundry of the American Locomotive Works, Dunkirk, New York.* (70) May.
Plumbing Rules and Regulations of the City of Rochester, N. Y.* (70) May.
Hot Water Supply by Indirect Heating, a Remedy for Incrustation Difficulties.* George Chasser. (Paper read before the British Inst. of Heating and Ventilating Engrs.) (70) May.
The Jointing of Tile Pipes. J. G. D. Armstrong. (Abstract from Official Report to British Congress on Sanitation.) (70) May.
The Importance of the House Drain. Dr. C. J. Whalen. (Abstract from paper read before the Chicago Medical Assoc.) (70) Serial beginning May.
The Heating and Ventilation of the New Tacoma High School.* (14) May 5.
Concrete and Concrete Block Sewers in St. Joseph, Mo.* (14) May 5.
The Use of Caissons in Bridge Building with Remarks upon Compressed Air Illness. Thomas Oliver. (29) May 11.
Refuse Destructor Combined with Electric Light Plant at Westmount, P. Q.* (13) May 24.
The Sewerage System of New Orleans.* (14) Serial beginning May 26.
Heating and Ventilating System of the New Custom House in New York.* (14) May 26.
A New Conduit for Underground Pipes.* (13) May 31.
Plumbing, Drainage and Water Supply in a Suburban Residence in the Vicinity of New York.* (70) June.
Water Supply, Typhoid Fever, Diarrheal Diseases, and Infant Mortality at Burlington, Vt., 1879 to 1905 Inclusive. M. N. Baker. (28) June.
The Municipal Electrolytic Hypochlorite Plant at Poplar.* (73) June 1; (26) June 8.
The Structural, Municipal and Sanitary Aspects of the Central Californian Catastrophe. Charles Gilman Hyde, Assoc. M. Am. Soc. C. E. (14) Serial beginning June 2.
Heating and Ventilating Plant of the Indianapolis Post Office and Custom House.* (14) June 9.
Some Notes on the Los Angeles Outfall Sewer.* W. P. Hardesty. (13) June 14.
Reinforced Concrete Sewer at South Bend.* (14) June 16.
Reclaiming the Site of Grant Park, Chicago.* (14) June 16.
Artificial Regulation of Atmospheric Humidity and Temperature.* (46) June 23.
Notes on Sprinkling Filters for Sewage Treatment: A Resumé of American and Foreign Experience. George W. Fuller, M. Am. Soc. C. E. (14) June 23.
Westmount, Quebec, Garbage Destructor. F. C. Fellows. (Abstract from Report to Town Council.) (60) July.
Experimental Methods as Applied to Water and Sewage-Works for Large Communities. George W. Fuller. (14) July 21.
Fads and Fallacies in Hot-Air Heating. R. S. Thompson. (Extracts from paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (13) July 26.

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**Sanitary—(Continued).**

The Use of Feed-Water Heaters in Connection with Heating Systems.* Wm. G. Snow. (Abstract of paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (13) July 26.

Beitrag zur Theorie der Schraubenventilatoren.* Carl Fred Holmboe. (48) June 9.

Ein Beitrag zur Frage der Klärung Stadtischer Abwässer. Franz Knipping. (51) Serial beginning July 11.

**Structural.**

The Inspection of Treatment for the Protection of Timber by the Injection of Creosote Oil. H. R. Stanford, M. Am. Soc. C. E. (54) Vol. 56.

The Theory of Continuous Columns.* Ernst F. Jonson, Assoc. M. Am. Soc. C. E. (54) Vol. 56.

An Analysis of General Flexure in a Straight Bar of Uniform Cross-Section.* L. J. Johnson, M. Am. Soc. C. E. (54) Vol. 56.

The Economical Design of Reinforced Concrete Floor Systems for Fire-Resisting Structures.* John S. Sewell, M. Am. Soc. C. E. (54) Vol. 56.

Cast Iron: Crushing Loads and Microstructure.* W. J. Keep. (55) Vol. 26.

Footings in Foundations.* Wilfrid Joseph Dilley. (63) Vol. 163.

The Puddling Effect of Water Flowing through Concrete.* William Ralph Baldwin-Wiseman. (63) Vol. 163.

Behaviour of Materials of Construction under Pure Shear.* E. G. Izod. (75) Feb.

Some Foundations for Buildings in Cleveland. Gen. J. A. Smith. (Paper read before the Civ. Engrs. Club of Cleveland.) (1) Apr.

Proportioning Concrete. Sanford E. Thompson. (Paper read before the Boston Soc. of Civ. Engrs.) (1) Apr.

Tests of Wisconsin Bricks. Heinrich Ries. (Paper read before the Wisconsin Clayworkers' Assoc.) (76) May.

Comparisons in Gasholder Design and Notes on Preservation of Structural Steelwork.* R. Nelson. (Paper read before the North of England Gas Managers' Assoc.) (66) May 1.

The Rational Proportioning of Structures in Ferro-Concrete.* (11) May 4.

Dome and Floor Construction in the United States War College.* (14) May 5.

Underpinning the Marshall Field Building in Chicago.* (14) May 5.

A Supplementary Report on the San Francisco Buildings by Prof. Derleth. (13) May 10.

The Recent Earthquake in Central California and the Resulting Fire in San Francisco. J. D. Galloway, M. Am. Soc. C. E. (13) May 10.

Injuries by Earthquake to the Buildings of Stanford University.* (13) May 10.

Hollow Concrete Foundation Piers.* (14) May 12.

Typical Systems of Reinforced Concrete Construction.* (46) May 12.

Waterproofing the Substructure of the West Street Building, New York. (14) May 12.

The Saving of the Western Electric Building at San Francisco. (14) May 12.

A New Magnesium Oxy-Chloride Cementing Material. T. W. Cappon. (13) May 17.

A Graphical Solution of the Knee-Brace Problem.* M. A. Howe. (15) May 18.

Some Structural Features of the New Custom House at New York.* (14) May 19.

Specifications for the Protection of Buildings Against Lightning. (13) May 24.

"Ferro Concrete."* Sven Bylander. (Paper read before the Soc. of Engrs.) (22) May 25.

The Rigidity of Constructive Materials.* James E. Howard. (14) May 26.

The Effect of the California Earthquake on Reinforced Concrete.* John B. Leonard. (14) May 26.

Notes on the Fireproofing in San Francisco Buildings After the Fire.* B. B. Holland. (14) May 26.

A Floor-Beam Scale in Parallel Co-ordinates. Lucien E. Picolet. (13) May 31.

Some Examples of Concrete Mixing and Delivery Plant.* Wm. G. Fargo. (Abstract of paper read before the Mich. Eng. Soc.) (13) May 31.

A Simple Method for the Calculation of the Bending Strength of Curved Pieces. S. E. Slocum. (13) May 31.

The Comparative Resistance to Fire of Stone Concrete and Cinder Concrete.* (13) May 31.

The Rattling Test as a Safe Method of Disclosing the Permissible Absorption of Paving Brick. Edward Orton, Jr. (Paper read before the National Brick Mfrs.' Assoc.) (76) Serial beginning June.

The Constitution of Hydraulic Cements. Dr. W. Michaelis, Sen. (Paper read before the Assoc. of German Portland Cement Mfrs.; tr. by Dr. W. Michaelis, Jr.) (67) June; (German) (80) July 12.

Coke and Ore Bins.* E. W. Pittman. (58) June.

The New Soap Factory Building of Armour & Co. at Chicago.* (14) June 2.

Underpinning the Criterion Hotel, New York.* (14) June 2.

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**Structural—(Continued).**

The Structural, Municipal and Sanitary Aspects of the Central Californian Catastrophe. Charles Gilman Hyde, Assoc. M. Am. Soc. C. E. (14) Serial beginning June 2.
Steel Structures in the San Francisco Disaster.* George Simpson. (20) June 7.
Reinforced Concrete and Fireproof Construction in the San Francisco Disaster. Maurice C. Couchot. (13) June 7.
Shearing Strength of Structural Steels.* Ch. Fremont. (From *Revue de Metallurgie.*) (22) June 8.
Reinforced Concrete Bar. (12) June 8.
Mechanical Compression of the Ground in the Construction of Foundations.* (46) June 9.
Cement for Building Construction. (Report of a Special Committee of the National Fire Protection Assoc.) (14) June 9; Abstract (13) May 24.
Tests of the Strength and Fireproof Qualities of Sand-Lime Brick.* Ira H. Woolson, M. Am. Soc. M. E. (Paper read before the National Assoc. of Mfrs. of Sand-Lime Products.) (13) June 14.
A British Investigation of Reinforced Concrete. (Statement issued by a joint committee representing six societies.) (14) June 16.
The Failure of Charing Cross Roof.* Major Pringle. (Abstract of the report of the Board of Trade.) (12) June 22; (22) June 22.
Two-Hinged Arch Trusses for the New Livestock Pavilion, Chicago.* (13) June 28.
Investigation of the Thermal Conductivity of Concrete and the Effect of Heat upon its Strength and Elastic Properties.* Ira H. Woolson. (Paper read before the Amer. Soc. for Testing Materials.) (13) June 28; (14) July 21.
Specifications for Foundry Pig-Irons. W. B. Parker. (Paper read before the Brit. Foundrymen's Assoc.) (22) June 29.
Purdue University Impact Testing Machine.* W. K. Hatt and W. P. Turner. (Paper read before the Amer. Soc. for Testing Materials.) (18) June 30.
The Electrolytic Corrosion of Structural Steel. Maximilian Toch. (Paper read before the Amer. Electrochemical Soc.) (14) June 30.
Some Steel Details in the Wanamaker Building, New York.* (14) June 30.
Underpinning the Grand Central Palace, New York.* (14) June 30.
The Foundation of the Myers Building, Albany.* (14) June 30.
The Design, Intsallation and Maintenance of the Modern Office Building.* Chas. Gobrecht Darrach. (3) July.
The Effects of Earthquake and Fire on Modern Steel Buildings.* Clarence Heller. (9) July.
The Physical Phenomena of the Penetration of Cement by Sea Salts. H. Le Chatelier. (From the *Proceedings* of the International Assoc. for Testing Materials.) (60) July.
Tension-Tests of Steel Angles with Various Types of End-Connection.* Frank P. McKibben. (Paper read before the Amer. Soc. for Testing Materials.) (13) July 5.
Reinforced Concrete Bank and Office Building, Los Angeles, Cal.* Max J. Welch. (13) July 5.
The Jones & Laughlin Steel Company's New Structural Mill.* (20) July 5.
The Armstrong College, Newcastle-on-Tyne.* (12) July 6.
The Underwriters' Laboratory Plant in Chicago.* (14) July 7.
Construction Features of a Model Abattoir.* (14) July 7.
Protective Coatings for Iron and Steel. Arthur B. Harrison. (Paper read before the Amer. Soc. for Testing Materials.) (14) July 7.
Underpinning a Tall Brewery Wall on Rock Foundations.* (14) July 7.
Shop Extensions at the Plant of the Allis-Chalmers Co., Milwaukee, Wis.* (13) July 12.
The Design of Reinforced Concrete Columns and Footings.* Edward Godfrey. (13) July 12.
Repeated-Impact Testing Machine at the National Physical Laboratory. T. E. Stanton. (11) July 13.
The Sand Blast for Testing Materials.* H. Burchartz. (14) July 14.
Concrete Column Tests at the Watertown Arsenal, Mass.* James E. Howard. (Paper read before the Amer. Soc. for Testing Materials.) (14) July 14; (18) July 21; (13) July 5.
The Comparative Advantages of Hard and Soft Steel for Reinforcing Concrete. Daniel B. Luten. (13) July 19.
Reinforced Concrete in the New San Francisco Building Law. (13) July 26.
Variations in Strength of Rolled Steel Plates due to the Segregation of Carbon.* (13) July 26.
Sand for Mortar and Concrete. Sanford E. Thompson. (Paper read before the Assoc. of Amer. Portland Cement Mfrs.) (19) Serial beginning July 28.
Influence de la Température de l'Eau dans Laquelle sont Conservées les Eprouvettes d'Essai sur Leur Resistance. M. Mercier. (43) 1er Trimestre, 1906.
Note sur les Murs de Soutenement en Maçonnerie avec Eperons en Béton Armé.* F. Chaudy. (32) Mar.

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**Structural—(Continued).**

Quelques Mots sur le Calcul des Planchers Reposant sur Poutrelles et sur Celui des Fermes Supportant les Toitures.* L. Lemaire. (30) Apr.
Les Constructions de Grande Hauteur a l'Epreuve de l'Incendie aux Etats-Unis d'Amérique.* E. Masson. (30) Apr.
Epreuve au Feu d'un Plancher en Ciment Armé.* (84) June.
L'Emploi des Pieux en Béton pour les Fondations.* (33) June 16.
Formänderungsarbeit der Eisenbetonbauten bei Biegung. Kazimir Grabowski. (79) Vol. 4.
Untersuchungen an Plattenträgern aus Eisenbeton. Max Möller. (Paper read before the Deutsche Beton Verein.) (51) Apr. 25.
Der Betonhohlstein, ein Neues Baumaterial.* Albrecht. (78) Serial beginning May.
Kontinuierliche Balken und Statisch Unbestimmte Systeme im Eisenbetonbau. G. Kaufmann. (78) Serial beginning May.
Beitrage zu den Versuchen mit Eisenbeton.* M. Marcichowski. (78) May.
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*Illustrated.

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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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## THE VENTILATION OF TUNNELS.

By Charles S. Churchill, M. Am. Soc. C. E.

To be Presented September 19th, 1906.

In 1904 the writer presented to the International Engineering Congress, Paper No. 43, on the "Ventilation of Tunnels."* Since that date improvements have been made in some of the tunnels and subways referred to, which are worthy of note, and the writer has obtained certain additional data, as to the condition of the air in some subways and tunnels in Europe, which are valuable for comparison in determining good practice.

*Gallitzin Tunnel.*—The ventilating plant at Gallitzin Tunnel, west of Altoona, on the main line of the Pennsylvania Railroad, was referred to in that discussion as being of the same type as that of the Elkhorn Tunnel, on the Norfolk and Western Railway, and as being practically completed at the date of the discussion.

This ventilated tunnel is 3 600 ft. long, and is built for a single track, being 17 ft. wide and 20 ft. 5 in. high, and is lined with concrete. Its sectional area is 324 sq. ft., and the cubical contents of

* Published, with articles by other writers on this subject, in *Transactions*, Am. Soc. C. E., Volume LIV, Part C, pp. 522–579.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

the whole tunnel are 1 166 400 cu. ft. There is an ascending grade of 0.5% from the east end through the tunnel, but the east approach is on a heavier grade, so that west-bound freight trains generally have a pusher engine at the rear of each in passing through the tunnel.

Plate XXXVII shows the general arrangement of the ventilating plant and all important details, its location being at the east or lower end of the tunnel.

With fans making 145 rev. per min. the observed flow of fresh air through this tunnel from east to west is at a velocity of 1 780 lin. ft. per min., equivalent to 576 000 cu. ft. per min. As usually operated, these fans make 130 rev. per min., while freight trains are in the tunnel, and the velocity of the air in the tunnel is 1 550 ft. per min., which results in 502 000 cu. ft. of fresh air being delivered through the tunnel each minute. With the fans running at this speed, the tunnel is cleared directly after the exit of a west-bound train. Excepting when freight trains are in the tunnel, the fans run at from 40 to 60 rev. per min.

There are, as shown by Plate XXXVII, two 8 by 16-ft. fans, one on each side of the track, each operated by a direct-coupled engine of about 200 h. p., the total rated horse power of the plant being 400. This ventilating device was put into regular operation in April, 1905.

*St. Clair Tunnel.*—The St. Clair Tunnel, on the Grand Trunk Railway, with its insufficient ventilation, is described in the *Transactions.**

On October 9th, 1904, six employees of the railway were killed in this tunnel by gas and smoke from a locomotive while necessarily standing in the tunnel on account of a break-in-two of a train. This accident is fully described in *The Railway and Engineering Review.*†

In lieu of installing a system of ventilation, the Tunnel Company has during this year contracted for the electrical operation of this tunnel by methods described in detail in *Engineering News.*‡

This will remove all danger from such causes, and very greatly reduce the discomfort of persons in the tunnel; but, nevertheless, in

* *Transactions*, Am. Soc. C. E., Vol. LIV, Part C, p. 529.
† October 15th, 1904, Vol. XLIV, p. 740.
‡ January 18th, 1906, Vol LV, p. 59.

the future some means of artificial ventilation may be found desirable, as in the case of the Mersey Tunnel, Liverpool.

*Park Avenue Tunnel, New York City.*—Park Avenue Tunnel, New York City, on the New York Central and Hudson River Railroad, is described in the *Transactions.** The work of providing for electrical operation, which was undertaken partly for the purpose of improving the ventilation, is rapidly progressing, under plans fully described, with official reasons therefor, in *Engineering News.*† The reasons given are, briefly: Improvement of ventilation, greater safety in operation, and increased capacity.

*Simplon Tunnel.*—This tunnel, which is 12.33 miles long, and is constructed for a single track, with one passing siding at the center, was completed early in 1906, and was formally opened on May 19th, 1906. The ventilating plants used during construction are described in *Transactions.*‡

When the writer visited this tunnel, in the summer of 1905, a steel sliding door at each portal was arranged so as to be raised and lowered by electric power. The plan at that time was to lower the steel door after the entrance of a train and to force fresh air from the fans at that end of the tunnel into and through the tunnel with considerable pressure.

The adoption of electricity as the power for handling trains through this tunnel has greatly simplified the problem of ventilation.

*The St. Gothard Railway Tunnel.*—This steam-railroad tunnel is 9.3 miles long, is located on light grades, and is double-tracked. It has a large section, the area being 603 sq. ft., or approximately 3.2 times the area of two trains occupying the tunnel section. The cars of trains while in the tunnel are lighted by gas.

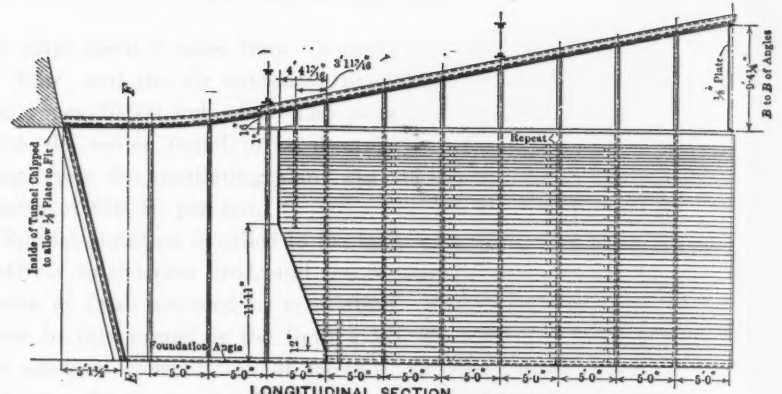
This tunnel is ventilated by a Saccardo plant, at Goeschenen, at the north end of the tunnel. It consists of two large fans operated by water power. Ventilation is secured by reducing the area of the tunnel section by about 38% near its northern end.

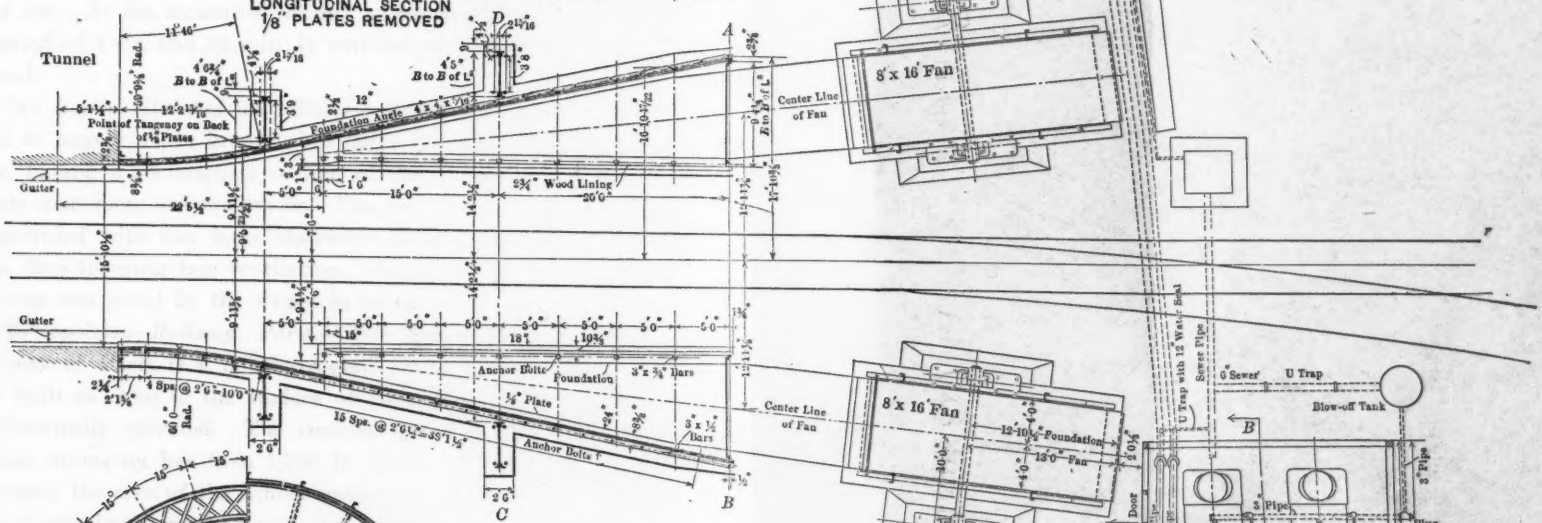
For comparative purposes, a sample of air was taken by the writer from a car of a north-bound train, running 30 miles per hr.,

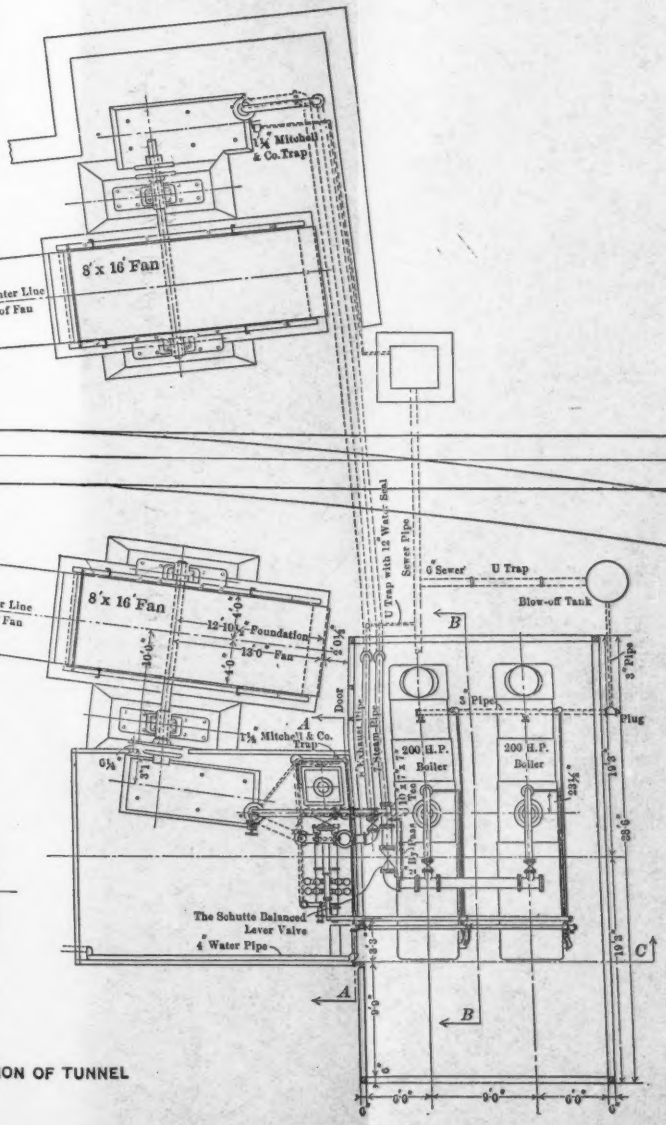
* *Transactions*, Am. Soc. C. E., Vol. LIV, Part C, p. 528.
† November 16th, 1905, Vol. LIV, p. 499.
‡ *Transactions*, Am. Soc. C. E., Vol. LIV, Part C, p. 531.

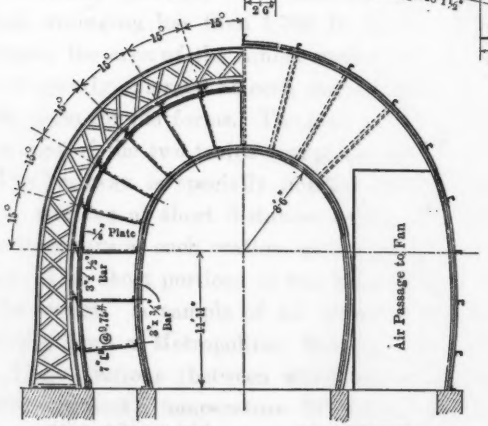
# GENERAL PLAN OF VENTILATING PLANT AT GALLITZIN TUNNEL, P. R. R.

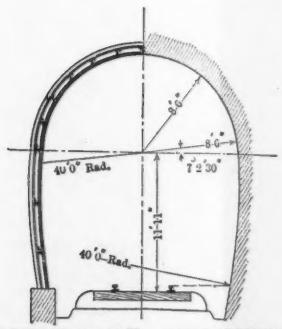
COMPLETED. APRIL 1905




HALF SECTION OF TUNNEL

at a point about 3 miles from the south end. The temperature was 82° fahr., and the air contained 10.19 parts of carbonic acid gas ($CO_2$) per 10 000 volumes. The measured quantity of fresh air which the writer found to be passing into the north end of the tunnel from the ventilating plant was 413 000 cu. ft. per min. at a velocity of 686 ft. per min.

Special attention is called to the large area of the tunnel section relatively to the cars used, and the consequent small velocity and volume of fresh air used in ventilation. The other favorable condition in this tunnel is the light grade throughout its length, so that the coal consumption of locomotives while in the tunnel is kept low. At the measured velocity of the ventilating air current, a period of 1 hr. and 12 min. is required to change the air in this tunnel.

*The Berlin Elevated and Electric Railway.*—This electric railroad is largely above ground, but there are short sections of subway, having a rectangular section of about 231 sq. ft., in which single span there are two tracks. The stations are roomy, and each is provided with two large stairways leading directly to the surface, thus insuring fair ventilation. The air in these short subway sections was noted by the writer as being good.

*Metropolitan Railway, Paris.*—The Metropolitan Underground Railway of Paris is a double-tracked arched tunnel, nicely lined, and built as close to the surface of the streets as practicable. It is electrically operated. The stations are comparatively close together, averaging less than 1 700 ft. apart. The two tracks are in one span, the area of the tunnel section being 315 sq. ft. This section is greatly enlarged at each station, thus providing in one span ample room for platforms. The area of the tunnel is approximately twice that of the two trains occupying the tunnel section.

This railway is specially notable for the large tunnel section, roomy stations at short distances apart, and the provision of two large stairways at each station, giving good direct outlets for ventilation. Two short portions of two lines of this road were examined by the writer. A sample of air taken at 7.40 o'clock on a bright morning, from a Metropolitan Railway car, between Palais Royal and Alma Stations (between which there were five stops at intermediate stations), temperature 70° fahr., contained 2.94 parts car-

bonic acid gas per 10 000 volumes of air, the outside air at that time containing 1.76 parts.

*The Mersey Tunnel, Liverpool.*—This tunnel is 2 miles long, has a section of about 425 sq. ft., and is provided with two tracks. It is now electrically operated, and is well ventilated by large fans.* The air in this tunnel is now good. A sample taken by the writer from a car in this tunnel, July 24th, 1905, contained 4.70 parts of carbonic acid gas per 10 000 volumes.

*The District Railway, London.*—The District Railway is a double-tracked subway, with its grade level generally as close as practicable to the streets above it, and with frequent openings to the surface, in addition to having stations approximately ½ mile apart. It is operated by steam, but it is being gradually electrified, primarily to secure better ventilation.

For comparative purposes, the writer quotes a test, made in 1902 for the London County Council, which showed that the air in a car contained 15.1 parts of carbonic acid gas per 10 000 volumes. A sample of air taken from a District Railway car by the writer, between Mansion House and Temple Stations, on a fair day, June 27th, 1905, at 4.25 P. M., temperature 76°, contained 11.27 parts of carbonic acid gas per 10 000 volumes, the outside air at that time containing 3.55 parts.

*Metropolitan Railway, London.*—The Metropolitan Railway is similar to the District Railway in construction and operation, and is also being gradually electrified, for the same reasons.

A test made in 1902 for the London County Council showed that the air in a car on this road contained 28.8 parts of carbonic acid gas per 10 000 volumes. A sample of air taken from a Metropolitan Railway car by the writer, between Gower Street and Portland Road Stations, on a very clear day, July 24th, 1905, at 12.40 P. M., temperature 74°, contained 14.07 parts of carbonic acid gas per 10 000 volumes, the outside air at that time containing only 1.75 parts.

*City and South London Railway.*—This electrically operated line extends from Angel to Clapham Road, about 6 miles, with thirteen stations on the entire line, the average distance apart being ½ mile.

* A detailed description may be found in the papers on the Ventilation of Tunnels, International Engineering Congress, St. Louis, 1904, *Transactions*, Am. Soc. C. E., Vol. LIV, Part C, pp. 527–558.

It consists of two single-track tubes, the inside diameter of each being 10 ft. 6 in. They are deep below the surface of the ground. As these tubes are small, the clearance around the trains is very narrow. The tubes are connected by small passages at the stations and by cross-overs near a few of them. The area of each tube is 86 sq. ft., the area of both tubes being, therefore, 172 sq. ft.; and one tunnel section equals about 1.4 times that of a train. The travel on this line is not as heavy as on some others, notably the Central London Railway. It is not ventilated artificially, and the air is not as good as in other tubes of the electric railroads in London. The only natural ventilation is through a stairway and generally three lifts at each station. The stairway has a minimum opening of from 35 to 40 sq. ft. One lift contains about 2 500 cu. ft., and has a capacity of about fifty persons. During ordinary light traffic only one of these lifts is required per train.

The draft produced in the tunnel by an approaching train lasts only 1 min., and amounts to only about 17 000 cu. ft. The draft that follows a train lasts about ½ min., and amounts to only about 8 000 cu. ft. At the stairway of Borough Station, at the time of the passage of a train, a down-draft was noted for 1 min., equal to about 7 000 cu. ft. of air, followed by an up-draft for ½ min., amounting to about 2 000 cu. ft. of air. In addition to this, each lift removes in its upward passage about 2 500 cu. ft. of air. This quantity per station is clearly insufficient to balance the vitiation of the air by the occupants of a train.

Tests made in 1902 for the London County Council showed that there were 14.2 parts of carbonic acid gas per 10 000 volumes of air in an empty carriage. A sample of air taken from a City and South London car by the writer, between London Bridge and Moorgate Stations, on a fair day, June 27th, 1905, at 3.45 P. M., temperature 74° fahr., contained 11.78 parts of carbonic acid gas per 10 000 volumes, the outside air at that time containing 3.55 parts.

Another sample, taken on July 24th, 1905, from a car of the same road between Elephant and Castle Station and London Bridge Station on a still brighter day, at 9.25 A. M., temperature 69° fahr., contained 8.69 parts of carbonic acid gas per 10 000 volumes, the outside air at that time containing only 1.75 parts.

The sample taken in June shows that the car air contained a

little more than three times the quantity of carbonic acid gas found in the outside air on that day, while the sample taken on July 24th, though lower in this gas, contained nearly five times the quantity found in the fine outside air on that day, and actually seemed to the sense fully as poor in quality as that taken in June.

*Central London Railway.*—This electrically operated line extends from Shepherds Bush to the Bank, about 6 miles, with thirteen stations in this distance, averaging ½ mile apart. It consists of two single-track tubes, each 11 ft. 6 in., minimum inside diameter, connected by passages at the stations, also by six cross-overs in the entire length. The area of each tube is 100 sq. ft., the area of both tubes being 200 sq. ft. The cubical contents of the entire railroad tubes are equal to about 6⅓ million cu. ft.

The natural ventilation is by a narrow stairway and about three lifts at each station. Mechanical ventilation of the tunnels is secured by a fan at Shepherds Bush Station, which draws in fresh air from the opposite end of the line—that is, Bank Station, and other stations at intermediate points. The fan is 5 ft. wide, 20 ft. in diameter, and makes 145 rev. per min. It is operated by electricity, and is rated at 300 h. p. Its capacity is 100 000 cu. ft. per min. It is operated from 1.00 to 4.00 A. M. (3 hr.), with the outlet doors at all intermediate stations shut, therefore it draws in fresh air from Bank Station. During the operation of the fan, the water-gauge pressure in the tunnel is 4½ in., and the linear velocity of the air in the tunnel is 500 ft. per min. The fan is also operated during each day from 11.00 A. M. to 5.30 P. M., or 4½ hr., all the doors of the passageways at the stations being open. This improves the air in the tunnels for about one-half the length of the line—that is, for the 3 miles nearest to Shepherds Bush Station—it also clears out the cars as they come to this last station.

The result of night pumping, as indicated by an anemometer placed in the tunnels at the Post Office Station (the first one west of Bank Station), shows that each week an average of 123.9 million cu. ft. of fresh air entered during the night pumpings, which is equivalent to 17.7 million cu. ft. per night. As the tunnels contain 6⅓ million cu. ft., they are cleared about 2¾ times each night.

The result of this night ventilation is shown by tests taken on February 15th, 1905, at the Marble Arch Station cross-over siding,

which is about half way between Shepherds Bush and Bank Stations. At 9.30 P. M. the air was found to contain 10.3 parts of carbonic acid gas per 10 000 volumes. The fan was started at 1.37 A. M., and at 2.15 A. M. the air at the same point contained only 3.7 parts, which was the same as that in the outside air.

The amount of natural ventilation procurable is shown by some other tests made during the same night. Between 9.30 P. M. and 1.00 A. M. (3½ hr.), the air in the tunnel had cleared slowly from 10.3 parts to 6.0 parts of carbonic acid gas per 10 000 volumes at the latter time. During these tests the temperature of the tunnels was 66½° fahr. Another test, taken on February 2d, 1905, with the fans not running, and when the outside air contained 4.4 parts of carbonic acid gas per 10 000 volumes, showed that the tunnel air averaged 7.07 parts of carbonic acid gas, while the air in a full car contained 10.7 parts.

The methods now adopted for ventilating the Central London Railway have been put into force since 1902, and the question of adding to this ventilating system is now being considered.

The first ventilating plant on this road was at Bond Street Station, but it has not been used since the installation of the present ventilating plant at Shepherds Bush.

A long series of tests made in 1902 for the London County Council showed that the air in the cars contained a minimum of 9.60 parts of carbonic acid gas per 10 000 volumes, at a time when the outside air contained 3.30 parts, and a maximum of 14.7 parts of carbonic acid gas per 10 000 volumes, when the outside air contained 3.30 parts.

A sample of the air taken from a Central London Railway car by the writer, between Chancery Lane and Post Office Stations, on a fair day, June 27th, 1905, at 1.55 P. M., temperature 76° fahr., contained 5.92 parts of carbonic acid gas per 10 000 volumes, at a time when the outside air contained 3.55 parts.

Another sample taken by the writer on July 24th, 1905, from a car on the same road, between Tottenham Court Road and Oxford Circus Stations, on a still brighter day, at 1.00 P. M., temperature 72½° fahr., contained 7.04 parts of carbonic acid gas per 10 000 volumes, the outside air at that time containing only 1.75 parts.

*Great Northern and City Railway, London.*—The Great North-

ern and City Railway extends from Moorgate Station to Finsbury Park, a distance of 3.43 miles. It is electrically operated and lighted, and there are six stations, varying from 2 000 to 6 200 ft. apart. Drayton Park Station, which is 4 200 ft. south of the northern terminus, is all in the open for 600 ft., therefore the main tunnel on this road extends from Drayton Park to Moorgate, a distance of 2.62 miles; the longest distance between stations being from Essex Road to Old Street, 6 200 ft. This line was put into operation in 1904, and is in many respects the best one examined by the writer. It consists of two single-track tubes, each 16 ft. inside diameter, connected by five small cross-passages at each of the station platforms, in addition to some cross-overs. The station platforms are generally 420 ft. long, to accommodate a standard train of seven coaches each 50 ft. long, carrying a total of 430 passengers. The special features of this subway are its large tubes and the large stairways and passageways, as compared with other London subways. Each of these items is claimed by the officials of the road to be a direct benefit in ventilation. The line is expected to handle 27 000 000 passengers per annum. The maximum train service arranged for is a 3-min. spacing, making 3½ miles in 13½ min., including 20 sec. for each of four intermediate stops.

The area of each tube is 190 sq. ft., the area of the two tubes being 380 sq. ft. The area of the tunnel, therefore, is about 1.8 times that of the large cars of the trains therein. The approximate cubical contents from the open end at Drayton Park to the closed end at Moorgate Station is 5½ million cu. ft.

Its natural ventilation is by two stairway passages at each station, the minimum area of each passage being 57 sq. ft., or a total of 114 sq. ft., in addition to that furnished by three lifts at every station, each having a floor area of 130 sq. ft., or cubical contents of about 1 500 cu. ft.

Its artificial ventilation, applied since the line was opened, is obtained by a fan, having a diameter of about 6 ft., located at Pool Street, which is 6 330 ft. from the Moorgate end of the tubes. This fan has a capacity of 1 000 000 cu. ft. of air per hour, and, as operated, forces fresh air through a heading 10 ft. in diameter into the up-tunnel—that is, toward Moorgate Station, in the direction of travel. A large part of this current travels to Moorgate Station

cross-over and then into the down-tube. The present practice is to operate this fan twice each day, during the busiest periods, from about 8.00 to 10.00 A. M., and from 5.00 to 8.00 P. M., so that a volume of fresh air practically equal to the cubical contents of the entire subway is forced into it each 24 hr.

As to natural ventilation: Measurements of the currents in the stairways on the arrival and departure of trains show approximately a total of down-currents for each train per station of 20 000 cu. ft., and about the same for up-currents. The total ventilation per train for each direction, therefore, amounts to about 90 000 cu. ft. On a 5-min. spacing of trains, each filled with 430 persons, the change of air per hour amounts to 1 080 000 cu. ft. in the entire subway, or 18 000 cu. ft. per min. However, as there are constantly four trains in the tubes carrying a maximum of 1 720 people, and as each person requires 30 cu. ft. of air per min., the total requirement is more than 51 000 cu. ft. of fresh air per min., in order to keep the tunnel air of the same quality as the outside air, or about 26 000 cu. ft. per min. in order not to increase the carbonic acid gas by more than twice the quantity in the outside air. These figures show why ventilation has been found necessary during the busy hours to maintain air of the desired purity even in this excellently constructed subway.

On March 5th, 1904, before ventilation was established, a test of the air in this subway was made by Dr. Critchley, with the following results: The air in the street was found to contain 4.5 parts of carbonic acid gas per 10 000 volumes, that of a car in the subway was found to contain 9.0 parts, the temperature being 61½° fahr.

On February 20th, 1905, Dr. Southerland found that the air on the platform in the subway at Old Street Station contained 4.48 parts of carbonic acid gas per 10 000 volumes, temperature 54° fahr., while that in a car approaching this station was found to contain 7.22 parts, the temperature being 55½° fahr.

A sample of air taken from a Great Northern and City Railway car, by the writer, between Highbury and Old Street Stations, on a very bright day, July 24th, 1905, a little after noon, temperature 68° fahr., contained 2.35 parts of carbonic acid gas per 10 000 volumes, the outside air at that time containing 1.75 parts.

*The Rapid Transit Railway, New York City.*—The subway sections of this railway are either four-tracked, of rectangular cross-section, or of two double-tracked cross-sections. The former is the one used on the busiest part of the line, below Forty-second Street. The stations on this portion average about 1 500 ft. apart. The area of this four-tracked cross-section is about 650 sq. ft. The sectional area of the tunnel therefore is 1.8 times that of the four trains occupying the subway.

This subway is of steel construction, with concrete, and is built quite close to the surface of the streets. The outlets to the street at the stations consist of from two to a maximum of eight stairways, which, while large enough for the people entering the stations, are not as direct as in some of the European subways, and have not a total outlet area as large in proportion to the tunnel cross-section, or to the number of trains and people in the subway at one time.

The writer predicted in 1904 that mechanical ventilation would be found necessary to secure a positive change of air.

On November 21st, 1904, a sample of air was taken from a car in the Rapid Transit Subway, between Forty-second and Twenty-eighth Streets, and one between Spring Street and Astor Place, and these were found to contain too great a percentage of carbonic acid gas. Again, on December 28th, 1905, at 4.00 P. M., the temperature being 60° fahr., a sample of air, taken from a car of the Rapid Transit Railway, between Twenty-third Street and Brooklyn Bridge Stations, was found to contain 15.58 parts of carbonic acid gas per 10 000 volumes of air.

The various tests of air made by the writer in London and Paris have shown that, except in the deeper subways, the air has as high a temperature as that outside. In the Rapid Transit Subway, during the summer of 1905, a considerably higher temperature of the air was recorded. This is another reason why it will become very urgent to establish a complete system of mechanical ventilation, for the health of the employees and the comfort of the patrons, as in the case of the subway tunnels in Boston, Liverpool, and London.

*Subway Tunnels Generally.*—Among the statements heretofore made are included records of the determination of carbonic acid gas ($CO_2$) in the London subways as well as in their cars. From

these data, also from other similar tests of air reported upon by the London County Council, in subway tunnels when they were not fully ventilated, the air found in subway cars contains about 45% more carbonic acid gas than the average air found in the subway tunnels and stations. Inasmuch as the patrons and a large number of the employees of a subway tunnel line spend most of their time in the cars, the vital fact to be determined, as to the health and comfort of these individuals, is the amount of carbonic acid gas in the cars themselves. Therefore, tests of air in subway tunnels and stations are simply somewhat indicative of the conditions that will be found in the cars. It may be anticipated that the amount of carbonic acid gas in the cars will be at least 45% more than in the subway tunnel, and in crowded cars the proportion of carbonic acid gas will be still greater.

The writer, therefore, has confined his investigations everywhere to the vital question, namely, the quantity of carbonic acid gas ($CO_2$) found in the ordinary cars of tunnels, and the tests by him were taken in cars ranging from one-fourth to one-half full. Any reports of the amount of carbonic acid gas found in subway tunnels or stations, therefore, should be increased by about 45% in order to obtain any fair idea of the conditions met by the passengers and employees themselves; so that, if a subway contains as much as 6.5 parts of carbonic acid gas per 10 000 volumes of air, there will probably be found in the cars 8.4 parts or more.

It has further been shown by detailed measurements of natural ventilating currents in the London subway tunnels, from the smallest to those of the largest section, that an insufficient quantity of air is drawn into them to ventilate all parts of them properly. While the portions having light traffic may at times be free from too large a proportion of carbonic acid gas, those parts having heavy traffic will contain an excess. The conditions of traffic in the Rapid Transit Railway of New York, for example, are such as to indicate the presence of much more carbonic acid gas in the cars while traversing the lower portions of the subway tunnel than in the remainder.

Proper ventilation is not secured unless all parts of a subway tunnel receive a sufficient quantity of fresh air to balance properly the vitiation of that in the cars by the occupants thereof, and this

result cannot be secured, as has been shown, except by an efficient system of mechanical ventilation that will distribute fresh cool air everywhere in the cars, as well as in the subway tunnel and its stations.

*Standard of Purity For Air.*—Much has been written as to what constitutes good air and what is dangerous. The most important test is the determination of the parts of carbonic acid gas ($CO_2$) in a given sample per 10 000 volumes. Ordinary air varies considerably, during different kinds of weather, from about 1½ parts to more than 4 parts of carbonic acid gas per 10 000 volumes, but the ordinary figure is about 4 parts. The best authorities state that the air in any subway should not contain more than twice the amount of carbonic acid gas found in the outer air (the two being nearly always directly compared), and that, therefore, the general limit is 8 parts of carbonic acid gas per 10 000 volumes. The "Factory Act" of England makes 9 parts of carbonic acid gas as the maximum in rooms, etc. The report to the London County Council in 1902 places the safe limit at 8 parts, as being the maximum that should exist in the air of subways; and that report states further that the number of bacteria in subway air was generally found to increase and decrease in proportion to the carbonic acid gas in the air. The writer, while investigating this subject in London, during July, 1905, learned that public opinion is very strong in demanding air in subways that shall generally not contain more than 8 parts of carbonic acid gas per 10 000 volumes of air, and that periodical attacks by the press are made, substantiated by detailed reports of noted chemists, against any subway tunnel where, for a period, air is found to contain more than this quantity of carbonic acid gas. Hence, it may be stated that 8 parts of carbonic acid gas per 10 000 volumes is the maximum proportion of carbonic acid gas that should be allowed in the air of cars in subway tunnels.

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# PAPERS AND DISCUSSIONS.

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## THE NARRAGANSETT BAY COAL DEPOT.

By Augustus Smith, M. Am. Soc. C. E.

To be Presented October 3d, 1906.

To every newspaper reader who followed Admiral Rojestvensky's progress to the Fushima Straits, the preponderating importance of coaling ship, and the seemingly continuous performance of it must have been strikingly apparent. To the men intrusted with the upbuilding of our Navy, this problem, then, ever since the retirement of the sailing man-of-war, has been of increasing importance.

It was at first deemed sufficient to depend on commercial stocks of coal, in the various ports visited by our vessels, and on commercial equipments for supplying coal to the fleet. Then, as the Navy expanded and the service became more dependent on the coal pile, it seemed to be desirable for the Government to have depots containing a stock of coal which could be relied on without reference to commercial conditions, other than those which might affect the price of coal delivered at the Atlantic seaboard.

Up to this point the United States only followed the lead of Great Britain. After the establishment of these depots was started, the wisdom of providing some form of coal-handling machinery, so

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

as to reduce to a minimum the cost of storing and withdrawing coal for distribution, and, more important from a naval standpoint, so as to reduce the time required for these operations, impressed itself on the minds of influential men in the Navy; and, in this application of labor-saving machinery, the United States Navy to-day stands foremost.

This undertaking means more, perhaps, to those who are well informed as to the state of the art of construction of coal-handling machinery than to the more superficial observer. The commercial machinery available had been developed to handle large quantities of coal daily, or at least at frequent intervals, and, in the case of many types, it required for its successful manipulation a crew of specially trained men working with the precision of a football team. Would such machinery be found satisfactory if used, perhaps, only two or three times a year?

Commercial requirements had evolved a type of machinery designed for dumping large quantities of coal into vessels more or less adapted to receive it as rapidly as it could be delivered from chutes. How could such devices be modified to serve war vessels designed primarily for fighting, and with coal bunkers arranged to fill space not otherwise required, or placed to protect the machinery and magazines rather than with a view of being readily filled by any known mechanical appliance?

While keenly alive to the difficulties to be overcome, the desirability for a successful or even partially successful result seemed to Naval officers worth a serious effort, and accordingly men were detailed to examine and report on all existing forms of coal-handling machinery, with a view to their adaptability to Naval requirements.

While it would doubtless be unjust to give all the credit for instigating this action to any one man, certainly much is due to the official and unofficial efforts of Rear-Admiral Royal B. Bradford, then Chief of the Bureau of Equipment, part of whose duty was to provide coal for the Navy in all parts of the globe. Admiral Bradford not only believed in installing mechanical appliances at those coal depots most frequently visited by our war vessels or likely to be visited frequently by them in time of war, but also continually urged the establishment of new and larger coal depots all over the world, wherever suitable sites could be secured. He thought it

would do no harm if the coaling station were a little more elaborate than perhaps might have answered the purpose, and his motto was: "The only way to have enough coal is to have too much."

Under such auspices, then, a Board was appointed, on November, 22d, 1899, consisting of Captain Henry C. Taylor, Captain C. H. Stockton, and Lieut.-Commander Herbert Winslow, to select a site for a coal depot on Narragansett Bay.

At that time the Navy Department had coaling stations at New London, Key West, Pensacola, San Juan and Hawaii. Those at Key West and New London were equipped with elaborate modern appliances.

The establishment of depots was also in progress at Frenchmans Bay, Dry Tortugas, Sitka, Mare Island and Samoa. The stations at Frenchmans Bay and Mare Island were to be fully equipped with the best coal-handling appliances available.

In addition to the foregoing stations, completed or in process of construction, the Bureau of Equipment was seeking to establish stations at Portsmouth, Boston, New York, League Island, Washington, Norfolk, Port Royal, New Orleans, Dutch Harbor, Puget Sound, San Francisco Bay, San Diego, Guam and Cavite. In addition to these, there were to be a number of smaller sub-depots at which, with the possible exception of Olongapo, no great stock of coal was expected to be carried.

Stations at Portsmouth, Boston, New York, Washington, Puget Sound and Cavite have been completed since that time, and stations at New Orleans and Olongapo are now under construction.

The investigations of the Board on Site for the Narragansett Bay Coal Depot led to the purchase of a tract of land containing about 160 acres, on the west side of the Island of Rhode Island, about 7 miles north of Newport, which offered a flat, wide foreshore in the shape of a cape or promontory of solid earth and gravel, providing a firm foundation for any structure which might have to be built. It was bounded on the west by deep water, thus giving access for the largest vessels, without requiring dredging. The normal rise and fall of the tide was only 4 ft. Through the upland part of the tract there flowed a small stream which could be depended on throughout the year for an ample supply of fresh water. All the water and water rights of this stream were secured by the

Government by the purchase of the land through which it flowed. A branch of the New York, New Haven and Hartford Railroad, running from Newport to Boston, passed through the property, and on the flat promontory jutting out into the bay and ending in Coggeshall Point there was a fresh-water lagoon, formed by the previously mentioned stream, covering about 30 acres, which seemed to be inviting for future conversion into a basin for harboring torpedo boats and small auxiliary-service vessels.

The land was fairly fertile, and sufficient was purchased to maintain the horses or other animals which might be found useful at the depot. The spot was healthful and even health-giving. Indeed, the property had belonged to the Government during the Civil War, and had been used for a convalescent camp and hospital. Fig. 4 is a plat of the property.

The strategical importance of Narragansett Bay, for the defense of the Coasts of the New England and Middle States, is well brought out in Captain Mahan's book,* in which he quotes from a private letter from the English Admiral, Sir George B. Rodney (afterward Lord Rodney), to the First Lord of the Admiralty, referring to Clinton's evacuation of Newport:

"The evacuating of Rhode Island was the most fatal measure that could possibly be adopted. It gave up the best and noblest harbor in America, from which squadrons in 48 hours could blockade the three Capital Cities of America—namely, Boston, New York and Philadelphia."

The site selected for the depot, therefore, may be described in one word—"ideal." It remained only to plan a coaling station commensurate with the opportunity, so as to utilize the full resources of the place.

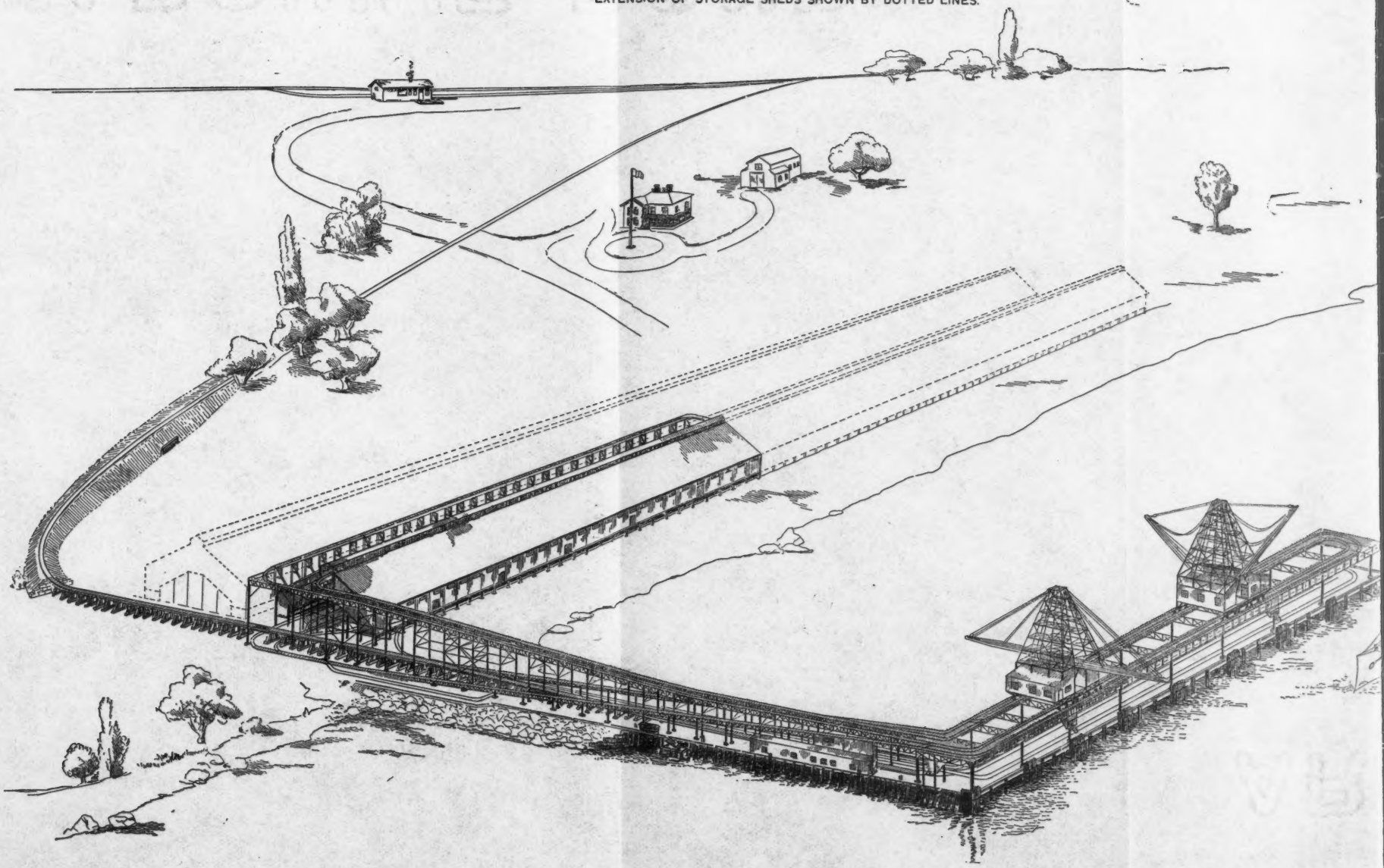
A Board was appointed, on August 7th, 1900, consisting of Captain George A. Converse (now Rear-Admiral, Chief of Bureau of Navigation), Captain C. S. Sperry, and Civil Engineer H. H. Rousseau, to prepare general specifications and estimates for the development of the property. This resulted in the establishment of the Narragansett Bay Coal Depot—the subject of this paper.

It was decided to build a wharf, parallel to the shore, with its outer face in 5 fathoms of water at mean low water, and to con-

* "The Influence of Sea Power upon History."

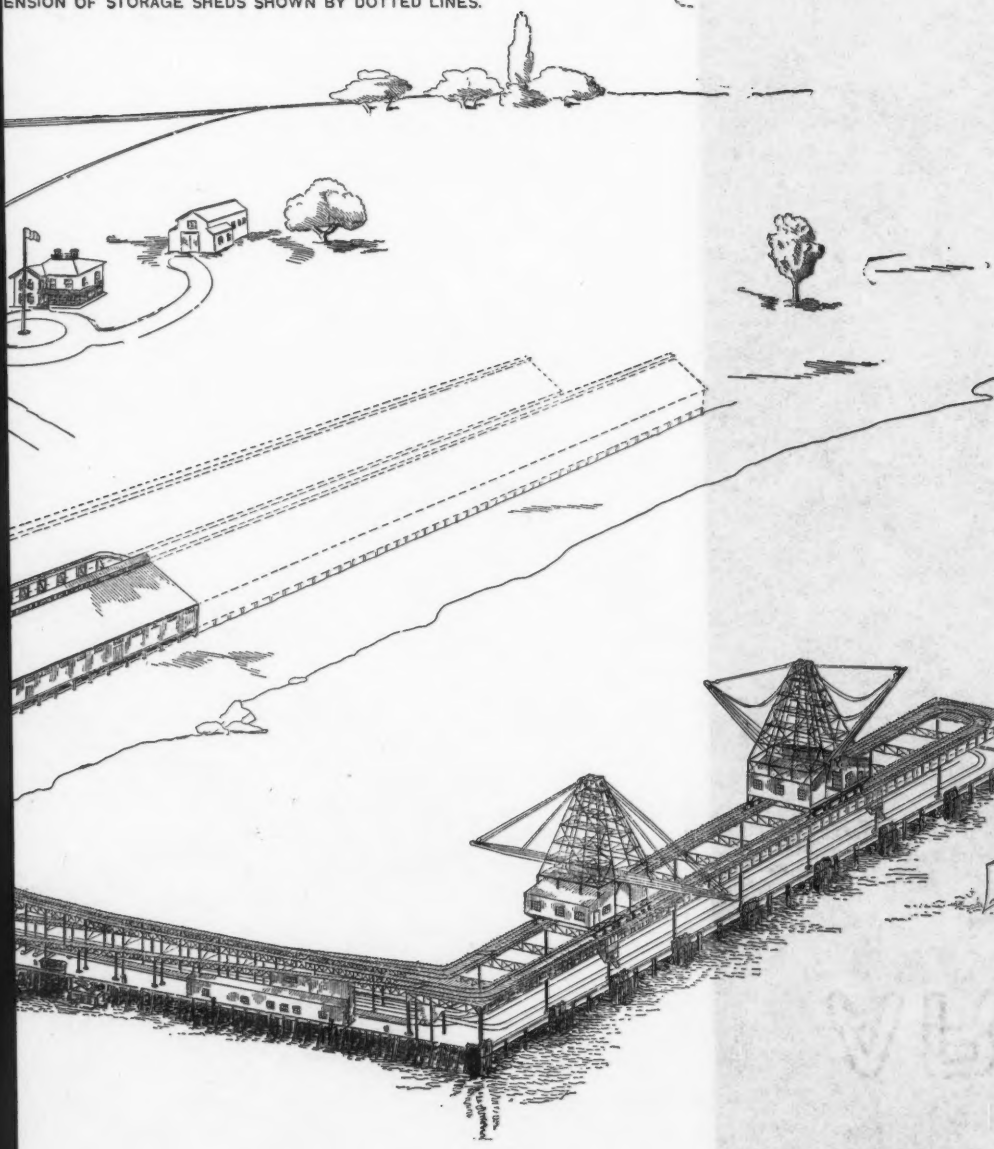
NARRAGANSETT BAY COAL DEPOT.

ORIGINAL INSTALLATION SHOWN BY FULL LINES
EXTENSION OF STORAGE SHEDS SHOWN BY DOTTED LINES.



NARRAGANSETT BAY COAL DEPOT.

ORIGINAL INSTALLATION SHOWN BY FULL LINES
ENSION OF STORAGE SHEDS SHOWN BY DOTTED LINES.





struct a silo or pocket for suitably housing the coal on shore, where such a structure could be built at less cost than over deep water. The Board anticipated receiving coal ordinarily by water, but recommended utilizing the railroad, also, as an alternate means of supply. It was recommended to commence the depot with a pocket having a capacity of 10 000 tons, arranged so as to be extended readily in the future. Two steam, digging cranes, for mining cargo coal out of vessels, were recommended for the wharf, and cable roads were suggested for carrying the coal from the wharf to the storage pocket on shore and from the latter to the wharf for distribution.

The Bureau of Equipment made an elaborate hydrographic survey of the premises, made borings, drove test-piles, and fixed the size and position of the wharf. It was to be 400 ft. long and 55 ft. wide, and to have its long side practically parallel to the shore and about 500 ft. from it. It was to be connected with the shore at the north end by an earth-filled approach out to the 5-ft. contour, and beyond that with a wooden pile wharf, of somewhat lighter construction than the main wharf, and 48 ft. wide.

The coal storage building was to be built so as to protect the coal thoroughly from the weather and be provided with gates or valves through which the coal could be withdrawn by gravity into the cable cars. It was to be constructed of metal or concrete, with hollow, cross fire-walls about 75 ft. apart, and equipped with suitable water pipes and hose. In addition to these precautions against fire, the depth to which the coal was to be piled in storage was limited to 15 ft., and thermostats were to be placed at frequent intervals throughout the coal pile and connected with an annunciator and alarm bell, so that any heating of the coal could be quickly detected and located. The cable roads had to be arranged so that, in the event of heating, coal could be readily withdrawn from any part of the pile and replaced at some other point, which would liberate the gas and give the coal a chance to cool.

These elaborate safeguards against fire were thought to be especially necessary for a Naval coal depot, where a pile of bituminous coal might be stored for a long time without being necessarily disturbed.

In order to stimulate the interest and co-operation of firms making a specialty of the construction of plants for the storage and handling of coal, as well as to avoid committing the Navy Department to the use of any patented appliance, the specifications prepared by the Board and subsequently issued by the Bureau of Equipment were of a general nature, setting forth the objects to be obtained and outlining the plan which seemed best suited for obtaining them, together with the usual stipulations governing the quality of material and workmanship required.

The subject, having been thus studied in its main features by the Naval authorities, was opened to civil co-operation, and competitive plans and specifications with tenders for construction were invited by public advertisement. The following extract from the specifications outlines the problem briefly as it was presented to prospective bidders:

"The objects to be accomplished by the coal-handling machinery are:

"*First.*—Removing coal from colliers or barges alongside the wharf and delivering into the shed.

"*Second.*—Removing coal from shed and delivery into collier or barge alongside wharf at any point along the outer or inner faces of the L, either in bulk, bags or baskets.

"*Third.*—Removing coal from shed and delivering aboard war vessels along the inner or outer face of L in a convenient manner, either in bulk, bags, or baskets.

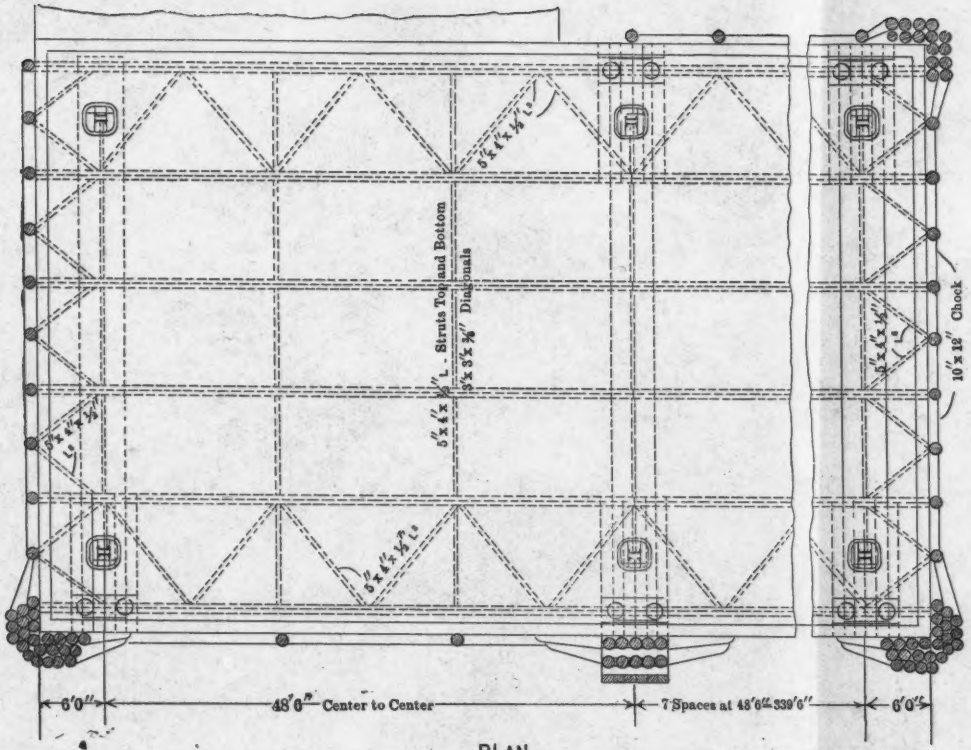
"*Fourth.*—Removing coal from railroad cars by hand, or by towers, if possible, and delivering into the shed or on board vessels alongside the wharf.

"*Fifth.*—Removing coal from the shed and delivering into railway cars.

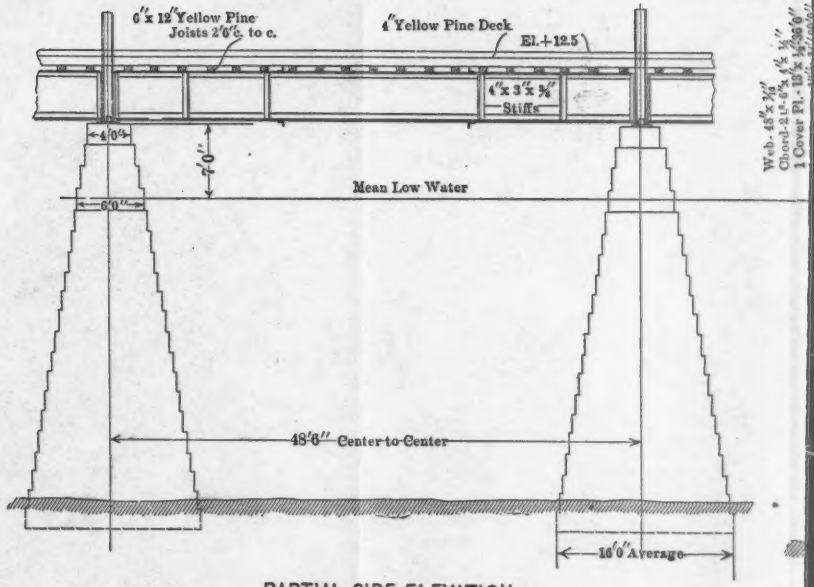
"*Sixth.*—Removing coal from the bottom of the pile in the shed and replacing it in the shed where desired.

"*Seventh.*—Removing coal from a vessel lying on one side of the wharf and delivering it on board a vessel on the other side of the wharf.

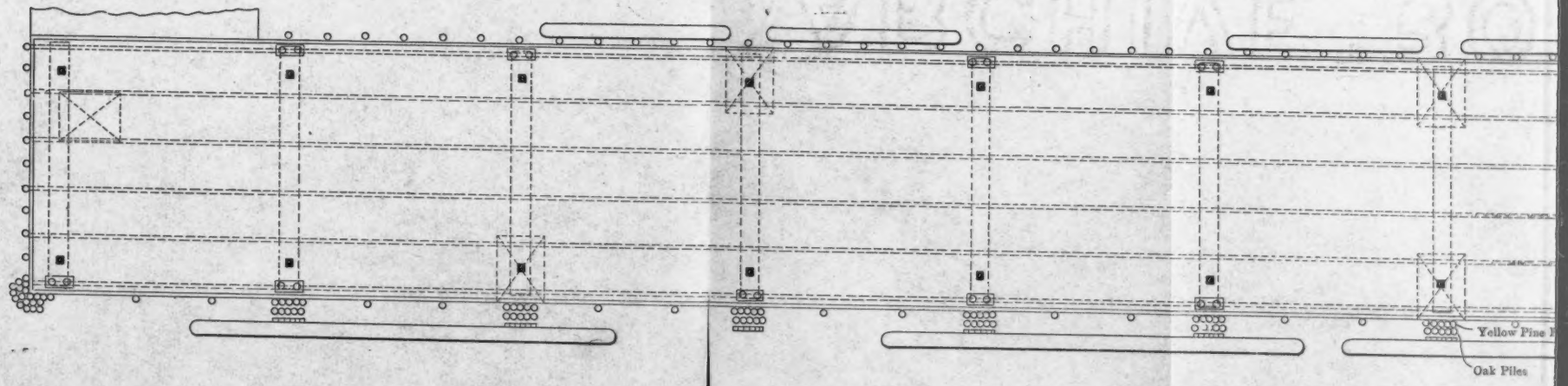
"The second and third of the above requirements are considered most important, and it is desired that the plant be equipped with all appliances that will enable all classes of vessels to receive coal rapidly by machinery, supplemented by all possible hand means, and as fast as possible by hand means alone."

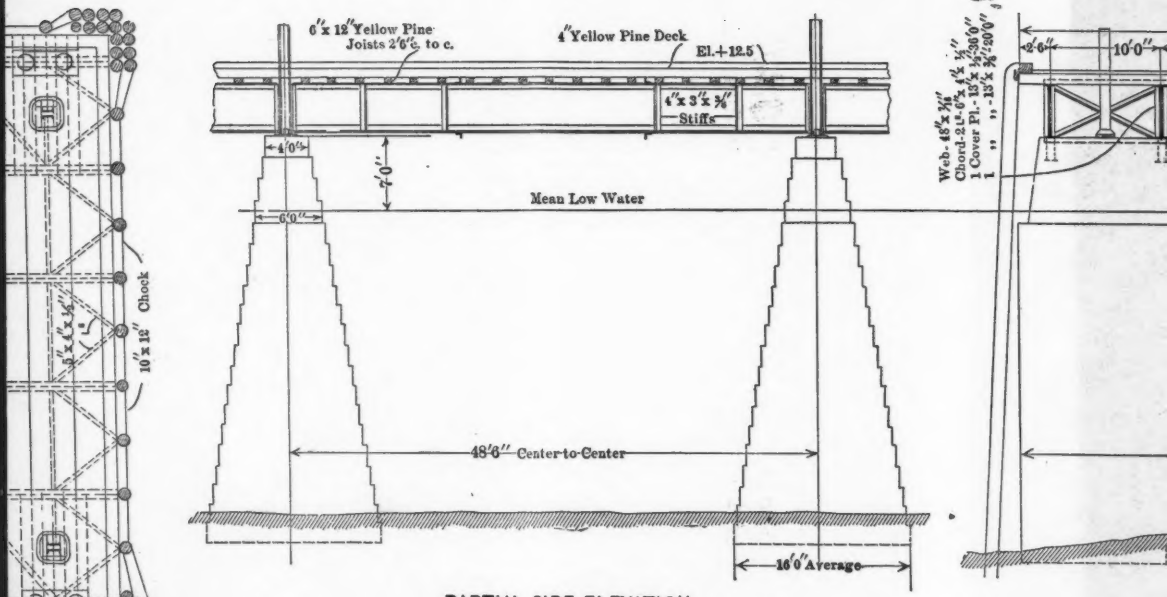



PLAN

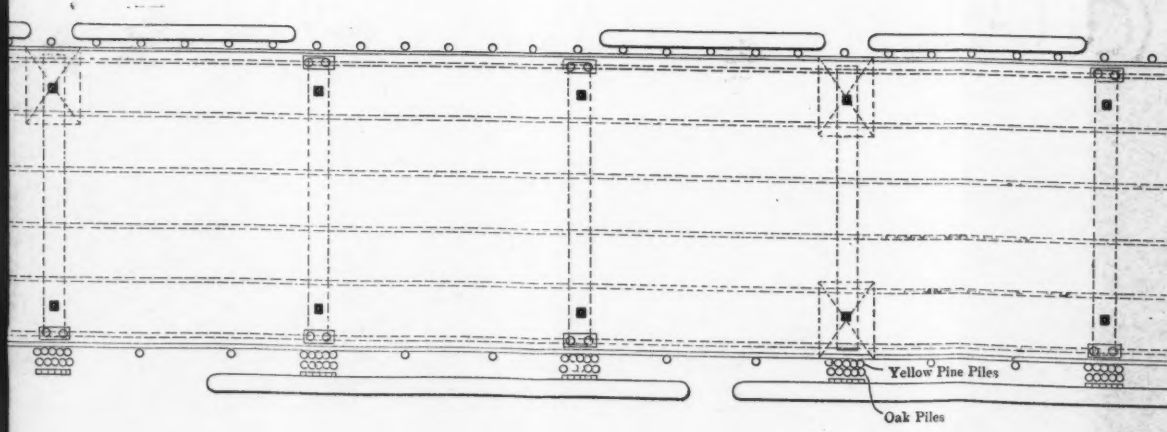


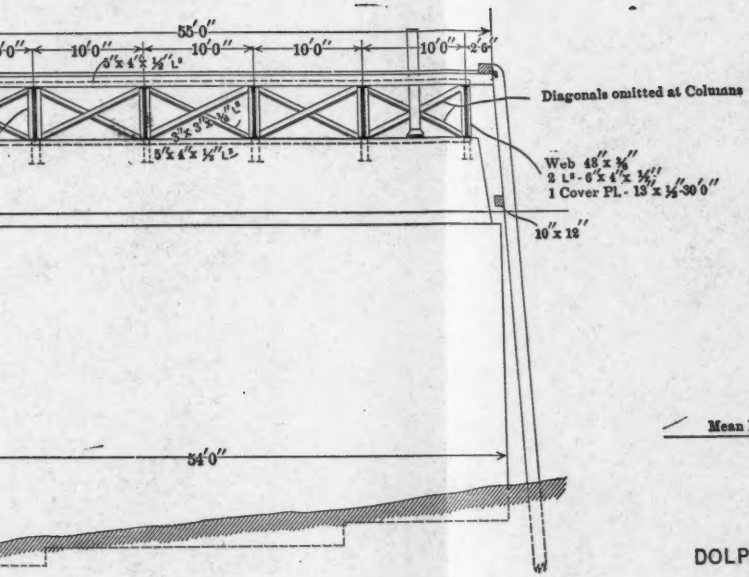

PARTIAL SIDE ELEVATION



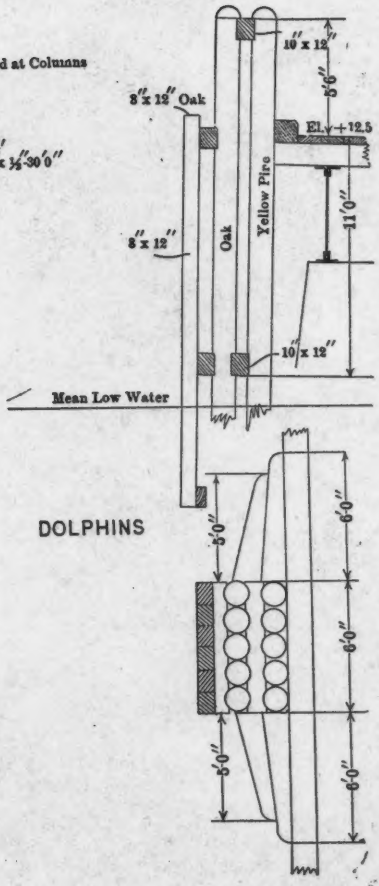



PARTIAL SIDE ELEVATION





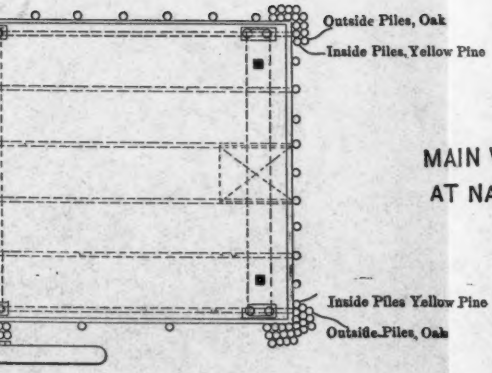

SECTION







DOLPHINS




MAIN WHARF FOR U.S. COALING PLANT
AT NARRAGANSETT BAY COAL DEPOT.

No limit of cost was imposed, though the bidders generally understood that the Bureau of Equipment expected to get a satisfactory installation for less than $500 000.

As was to be expected, even with the very carefully prepared specifications issued, the plans and prices submitted varied greatly. No less than thirteen essentially different plans were received from six bidders, and many of the bidders included various more or less important modifications of their fundamental idea, so that forty-two formal bids or prices were submitted to the Chief of the Bureau of Equipment to consider and make an award.

The contract was finally awarded to the writer, on one of his plans, slightly modified to meet the views of the Bureau, for $349 137, and construction was at once commenced. Plate XXXVIII is an orthographic projection of the design selected. The storage sheds shown in dotted lines were added subsequently under another contract.

A brief description of the plan adopted may be commenced with the main wharf. This consists of nine granite piers, 16 by 55 ft. on the bottom and 4 by 52 ft. on top, finishing at 7 ft. above mean low water, which made the average height of the piers about 35 ft.

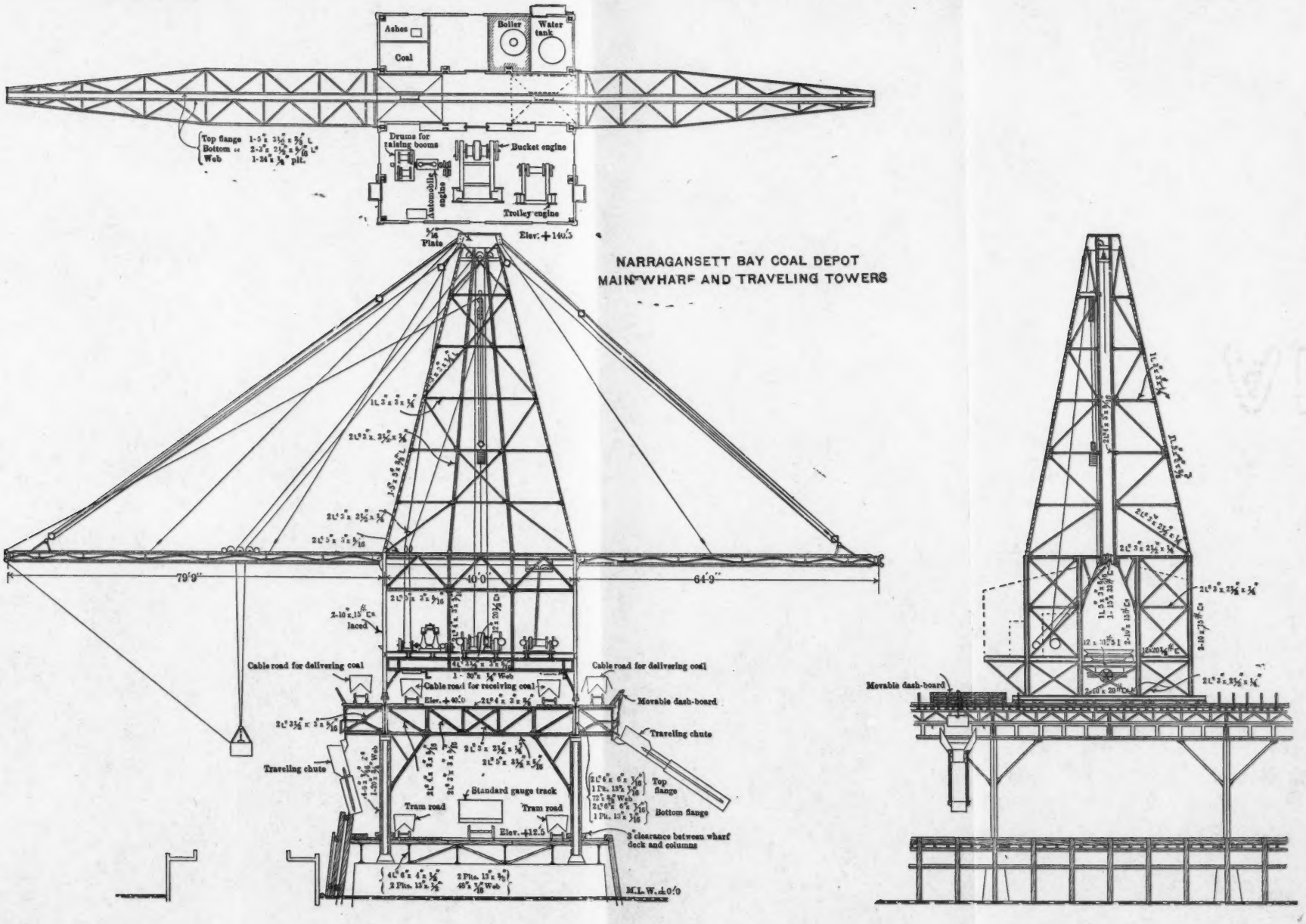
Below mean low water these piers were of granite blocks, averaging about 3 tons in weight, cut to approximately rectangular prisms of about the same shape as bricks, and laid in good bond, with open joints, by a diver. There was no dredging for the footing course except that done by the diver with a hoe. It was expected that the piers would settle about 18 in. into an overlying stratum of sand, which settlement, with the construction adopted, would do no harm if it ceased before the pier above mean low water was laid. The portion of the pier above mean low water was laid with closer joints, in Portland-cement mortar. It should be noted that the portion of each pier below mean low water weighed in water about 900 tons, while the portion above that level weighed about 150 tons. The superimposed weight of the wharf and superstructure resting on each pier was estimated to weigh not more than 100 tons. As soon as each pier reached mean low water level there was placed on it a load of granite blocks weighing considerably more than the total weight of the cement-laid portion of the

pier, the wharf, deck and superstructure, which load was allowed to remain until all settlement had ceased. In one sense, it was fortunate that there was great delay in securing the iron superstructure of the wharf, for the settlement of the main piers did not cease as soon as was expected.

Accurate measurements could not very well be made until the top of the pier showed above mean low water, and then accurate readings were taken with a level about once a month until the settlement had stopped entirely for two months. The observed settlement after the piers showed above mean low water was approximately 5 in., and was remarkably uniform. Undoubtedly, the total settlement in the bottom was considerably more than this, as the initial settlement under the 900 tons must have been quite rapid.

Of course, the primary object in adopting such a questionable method was to save the expense of dredging, and it might be worth noting here that the writer would not favor repeating it for work of similar importance, though, as far as can be detected, no further settlement of the wharf has taken place, and it has now stood true to line and grade since August, 1902.

The piers are 48 ft. 6 in. apart from center to center, and on them six rows of steel-plate girders are laid, designed to carry a distributed dead load of 400 lb. per sq. ft. These girders are thoroughly braced by angles having a minimum thickness of $\frac{3}{8}$ in., so as to resist the shock of a vessel as one solid frame, 50 by 400 ft. in area, weighing nearly 300 tons without the deck, which weighs about 400 tons more. The friction of this weight was relied on mainly for withstanding the impact of ships, and the anchor bolts securing the ironwork to the masonry were made small enough to shear, in the case of excessive strain, without injuring the masonry substructure. The deck and joists are of hard pine, with oak fenders and fender piles. A somewhat ingenious fender pile construction was devised by the Bureau, and is shown in detail on Plate XXXIX. The prototype of this was found in the fenders at the pier of the Fall River Line, in Newport. By this device the resiliency of two sets of piles was utilized in absorbing the momentum of an approaching vessel. Thus far, the fenders have been very satisfactory. The general construction of the wharf will be understood better by reference to Plate XXXIX.




NARRAGANSETT BAY COAL DEPOT
MAIN WHARF AND TRAVELING TOWERS

Starting again from the piers, and quite independent of the steel and woodwork of the wharf, there are 18 steel columns, 2 on each pier, to carry the viaduct on which the unloading towers travel. These towers also support the wharf loops of the cable road. The cross-section of this structure is shown on Plate XL. It was carried to a height of 40 ft. 6 in. above mean low water and no higher, in order to keep the grade of the cable road (used in bringing coal out from under the storage pocket, to the top of the trestle) from exceeding 7%, which was specified as a maximum by the Bureau of Equipment. Experience has proved that if the delivery track on the wharf trestle had been 10 ft. higher, it would have been more convenient for delivering coal to vessels having a high freeboard.

Two cranes or towers were provided for mining coal out of vessels, in which it is generally received at the depot. One of these cranes is shown on Plate XL. They are equipped with outshore booms having an effective reach of 60 ft. from the outer face of the wharf, and inshore booms having an effective reach of 45 ft. from the inner face. These booms are arranged to fold up in order to clear the masts of vessels lying at the wharf. A 1-ton clam-shell bucket is operated by friction drums mounted directly on the crank shaft of a hoisting engine having 14 by 24-in. double cylinders. The two wire cables, to open and close the bucket, pass over sheaves in a trolley free to move horizontally on the boom and thence over sheaves in the top of the tower to the main winding drums. The weight of the bucket is sufficient to bring the trolley home toward the center of the tower, and a separate engine having 10 by 15-in. double cylinders hauls the trolley out toward the end of either boom with a continuous rope passing over sheaves in the end of each boom.

This type of machinery has been perfected, and was installed by the Mead-Morrison Manufacturing Company, of Boston and New York. It is known as direct-connected machinery of the two-men type. The bucket is handled by two independent operators, one of whom moves the trolley while the other opens, closes and raises the bucket. After some practice, the men become wonderfully expert, and work in such harmony that the bucket describes a curve resembling a parabola—one operator arranging the ordinates while the other adjusts the abscissas—and it has been demon-

strated that the expense of the extra man is more than repaid by the greater speed attained. These towers have been worked for a short time at the rate of nearly 200 tons per hour for each tower, and the men have no difficulty in maintaining a rate of 100 tons per hour as long as there is coal within reach of the bucket.

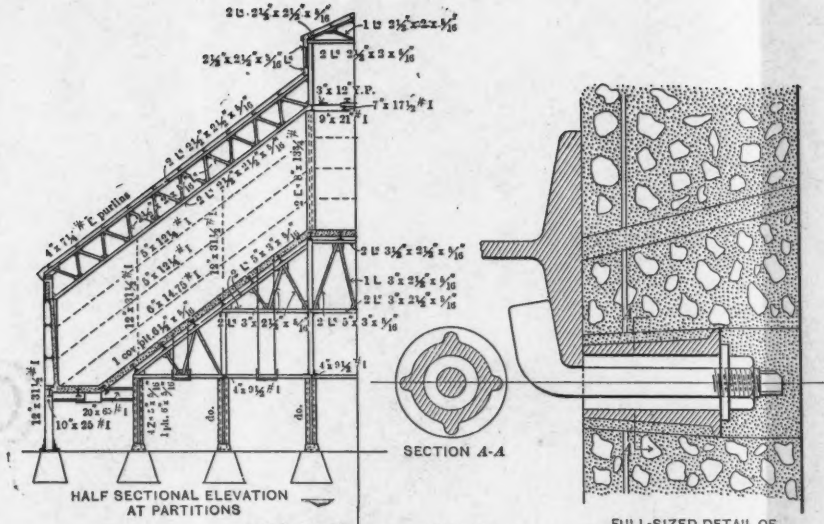
The low trestle, previously referred to as a defect in discharging coal from the station, has an offsetting and obvious advantage in taking coal into the station. It might be said, however, that such high rates of speed in taking coal into storage are of doubtful utility in the case of a Naval coaling station. The rate required by the Bureau of Equipment in the case of this installation was only 50 tons per hour for each tower.

The booms on these towers are raised and lowered and the towers propelled along the viaduct by a separate engine having two 7 by 8-in. cylinders. A 100-h. p. vertical boiler, supplying steam at 80 lb. pressure, with a large water-tank and coal-bin, was set up in a boiler-room entirely separate from the engine-room, as shown by the drawing. The isolation of the boiler-room from the engine-room has proved to be not altogether advantageous though it was almost a necessity in towers of the type adopted. The towers are estimated to weigh about 135 tons each. They travel on a track of 40-ft. gauge from center to center of rails.

The object of having the long outshore boom was to handle coal in tubs brought on platform cable cars for delivery to any point on the deck of a battleship lying alongside. This tremendous reach fixed the height of the tower, and was a factor in fixing the base in order to obtain the necessary rigidity.

Thus far, the operation of lifting loaded tubs of coal across the decks of naval vessels has not been looked upon favorably by captains coming for coal, and if this function of the tower is not to be utilized, it is regrettable that the long boom was provided, thus making the towers more heavy and unwieldy than was strictly necessary.

It will be seen that the towers, as built, comply with all the requirements of the Bureau of Equipment. They can be used for unloading coal from vessels lying at either side of the wharf; for lifting coal in tubs off platform cars delivered by the cable road to



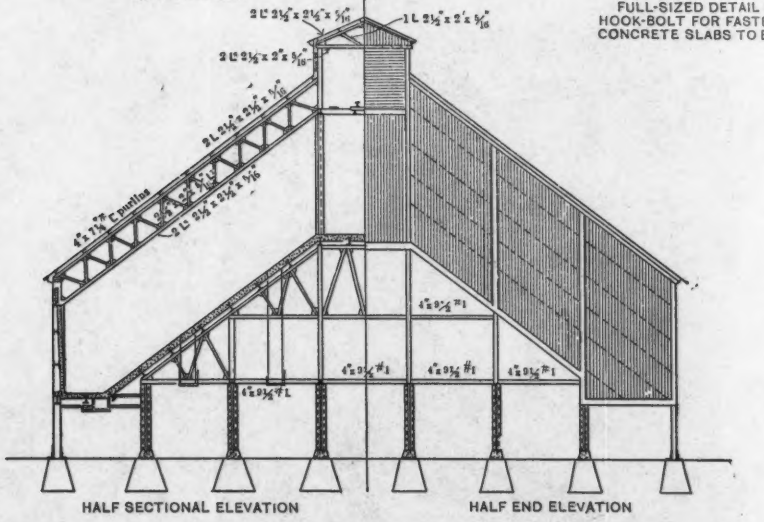


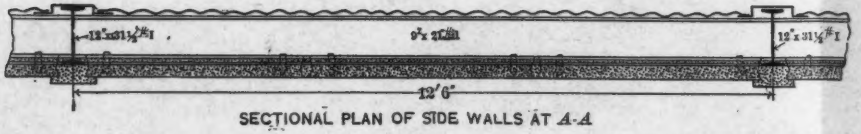


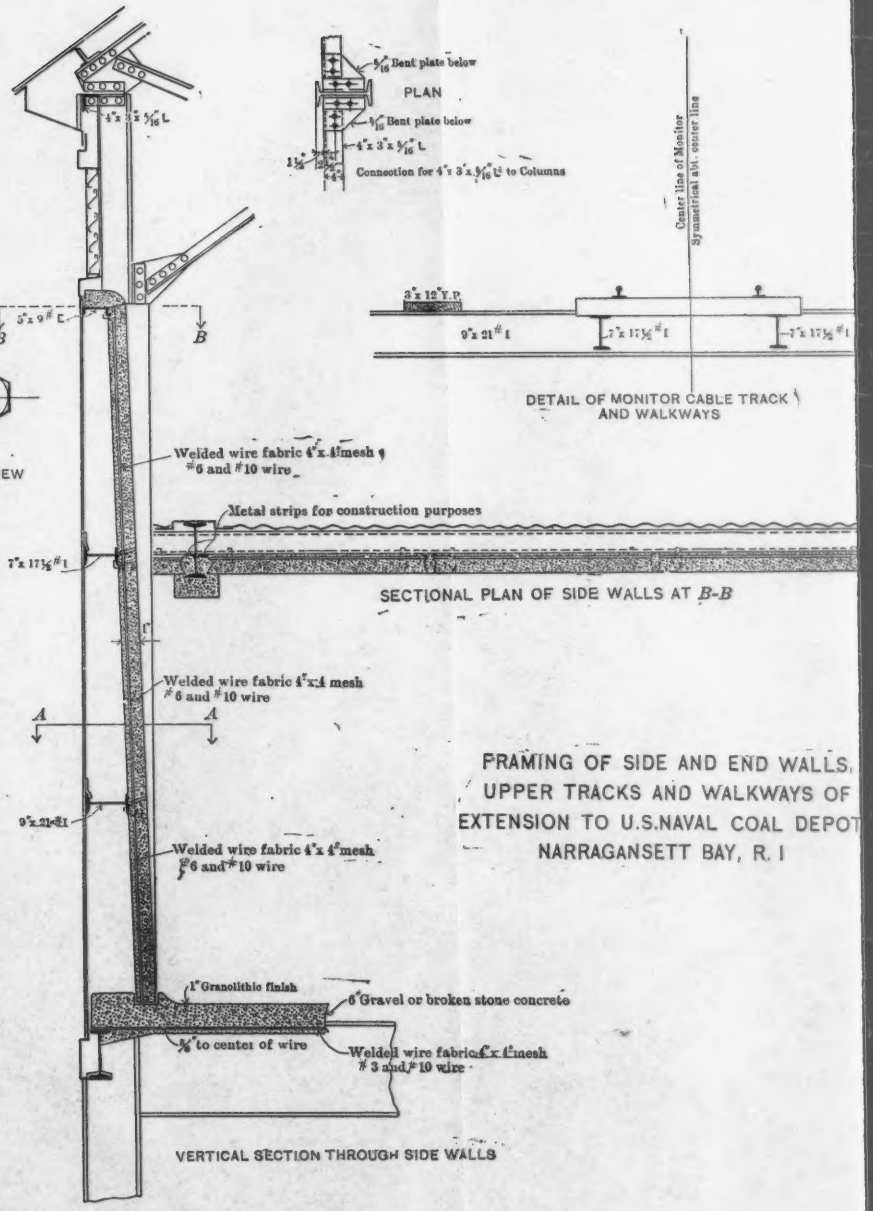




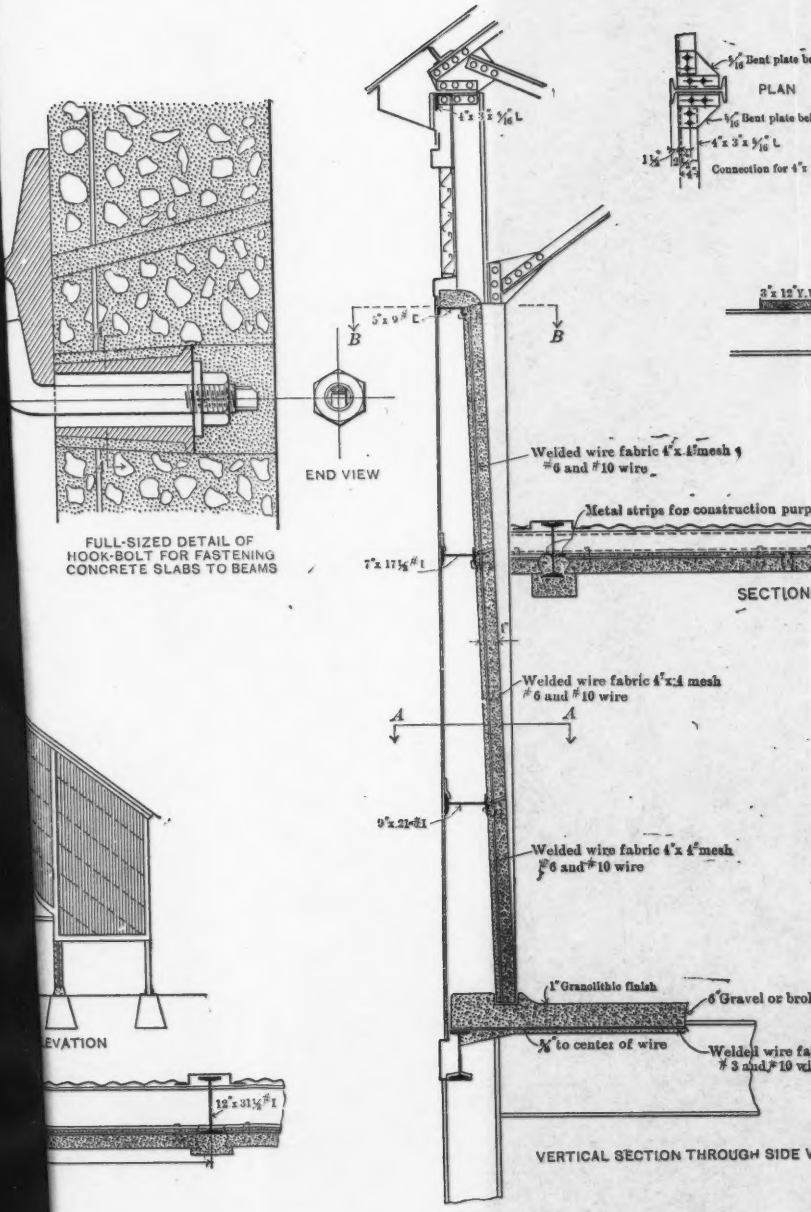




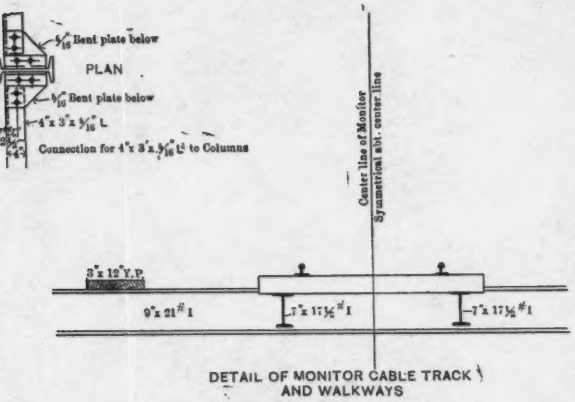




FRAMING OF SIDE AND END WALLS,
UPPER TRACKS AND WALKWAYS OF
EXTENSION TO U.S.NAVAL COAL DEPOT
NARRAGANSETT BAY, R. I




FULL-SIZED DETAIL OF HOOK-BOLT FOR FASTENING CONCRETE SLABS TO BEAMS

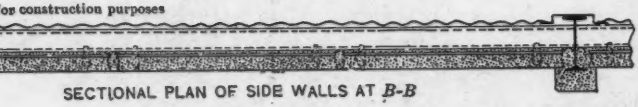
EVATION




DETAIL OF MONITOR CABLE TRACK AND WALKWAYS

x 4" mesh

op construction purposes

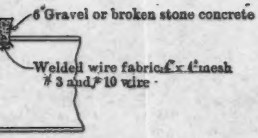


SECTIONAL PLAN OF SIDE WALLS AT *B-B*

4 mesh

FRAMING OF SIDE AND END WALLS, UPPER TRACKS AND WALKWAYS OF EXTENSION TO U.S.NAVAL COAL DEPOT NARRAGANSETT BAY, R. I

x 4" mesh




N THROUGH SIDE WALLS

serve vessels lying on either side of the wharf; for transferring coal from a vessel lying on one side of the wharf to a vessel lying on the other side; for mining coal out of railroad cars switched to a standard-gauge track, carried down the center of the wharf on the main deck, as shown on Plate XL, which coal could be deposited either in a hopper for transmission by the cable road into the storage building or directly to a vessel lying on either side of the wharf. In addition to this, the booms have been designed with sufficient strength to permit the towers to be used as cranes in an emergency, as they have a lifting capacity of 20 tons for a limited reach.

The hopper in the tower, intended to receive coal from the clam-shell bucket and transfer it to the cable cars which take it into the storage building, was built on a track so that it could be shifted from one side of the tower to the other, as indicated by the dotted lines. This was done so that the hopper could be placed as near as possible to the boat to be unloaded, and thus save travel for the clam-shell bucket and a reversal of strain in the cable controlling the trolley.

From the hopper in the towers, the coal is taken away on a cable road equipped with steel cars, having a capacity of 2 tons each, and arranged to discharge automatically, by side-opening doors, released by a trip set in the track at any desired point. The cable track is carried by a steel trestle, rising at a 7% grade to the top of the storage building, which was constructed on shore at some distance from the main wharf, for reasons previously stated.

The construction of the storage building is shown by Fig. 1. Concrete piers were carried below the frost line and spread out so that the pressure on the soil was reduced to a little more than 2 tons per sq. ft. On these piers a steel frame, carrying ferro-concrete floors and walls, and roofed with galvanized, corrugated iron, forms the coal storage pocket. Owing to the slope of the floor, 9 in 12, the depth of the coal, while 15 ft. measured vertically, is only 12 ft. when measured normal to the surface. Notwithstanding this shallow depth, one consignment of coal has already shown a dangerous tendency toward heating.

Galvanized corrugated-iron walls, with pilasters covering the steel posts of the building, were built around the sides and ends of

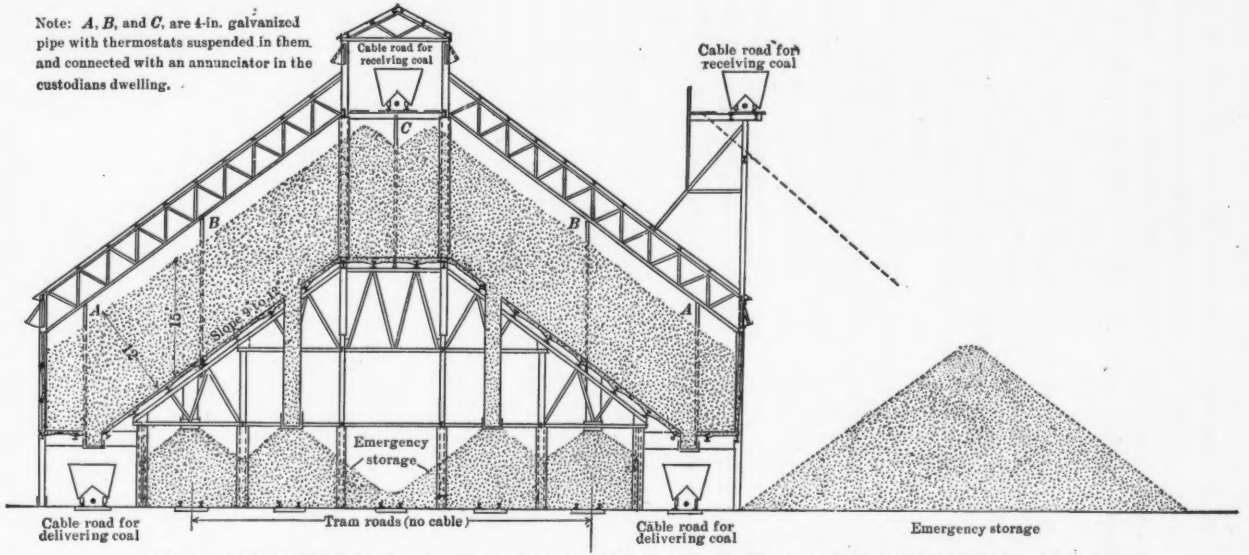
the pocket, partly for the sake of the appearance, and partly, perhaps, with a view of protecting the thin concrete walls from the action of frost.

The latter precaution was probably unnecessary, and in future construction of a similar kind it might be advisable to save the cost of the outer sheet-metal covering. In the case of this building, the double walls involved some difficulties in construction. It was decided to put up the corrugated iron first so as to secure it thoroughly to the steel framework of the pocket, and protect subsequent construction work from the weather. It was then found to be impracticable to withdraw the outer centering of the concrete wall, and this had to be left in the space between the concrete wall and the outer sheet-metal covering. If the alternate method of building the concrete wall first had been adopted, the sheet-metal covering would have had to be secured by nails to wooden nailing strips, as there was not sufficient space between the walls to permit of riveting. In either case, some wood had to be left in the space between the walls of a supposedly fire-proof storage shed.

In an extension to this depot, subsequently contracted for by the writer, and consisting of three additional storage buildings equal in size and similar in construction to the first, this difficulty was overcome in the following way:

The walls and partitions of the building were made of cast concrete slabs, 4 in. thick and about 4 ft. square, in which a reinforcement of Clinton wire-cloth had been inserted. After these slabs had hardened from 2 to 6 weeks, according to the time of year, they were lifted into the building and secured to the steel framework by special hook-bolts, very much as slabs of slate might be set. This method of construction insured a much stronger wall than in the original pocket, as each slab could be thoroughly inspected, and the handling incident to transferring the slab from the place of manufacture to its final place in the wall served as an effectual test of each and every piece. The cost of the construction was also found to be in favor of the cast-slab method.

Plate XLI shows the construction of the extension. The coaling station now has a capacity of 40 000 tons above the inclined floor, subject to a gravity discharge, and additional space for about 20 000 tons under the building, without piling the coal more than 12 ft.




CROSS-SECTION LOOKING NORTH THROUGH STORAGE BUILDING, NARRAGANSETT BAY COAL DEPOT

FIG. 1.

deep. At the time the extension was made, the floors under the building were paved with concrete.

The central columns projecting through the coal above the inclined floor, are protected by concrete in metal cylinders of about 11 in. outside diameter. The columns next to the ground are protected by similar concrete coverings in metal cylinders 15 in. in diameter. Hot coal, therefore, could do little damage to the steel frame of the building and the steel is not exposed to the corrosive action of the coal at any point.

In the outer row of protected columns under the building grooves are cast in the concrete covering for the insertion of flash-boards, to assist in confining the coal in the auxiliary storage space on the ground.

In the original building, the cable road taking the coal into the building was returned over a trestle carried by a continuation of the east line of columns through the roof, which was also intended to serve for forming a large auxiliary pile of coal on the ground east of the shed in an emergency. (Fig. 1).

When the storage building was extended, this trestle was taken down and the cable track returned through the monitor of the new east shed.

A separate cable loop had to be provided on the ground to withdraw coal from the east shed, and the tracks were arranged so that cars could be switched from either shed to either cable. The tracks shown under the middle spaces of the storage buildings are tram tracks on which cars have to be backed by hand, in case the auxiliary storage under the building is utilized. These cars would be pushed out to the cable track at either end of the building and be moved to the wharf by the cable.

One of the problems was to find for the bottom of the pocket a gate or valve which could be operated with ease and certainty by one man, so as to fill the cable cars without spilling coal on the track, and do this rapidly enough to dispatch a loaded car every 30 seconds.

An overhead gate was sought, in order to save headroom, and the difficulty of handling large lumps of bituminous coal was finally overcome by adopting the gate shown by Fig. 2. It will be seen that the jaws of this gate do not meet, so that there is no chance for

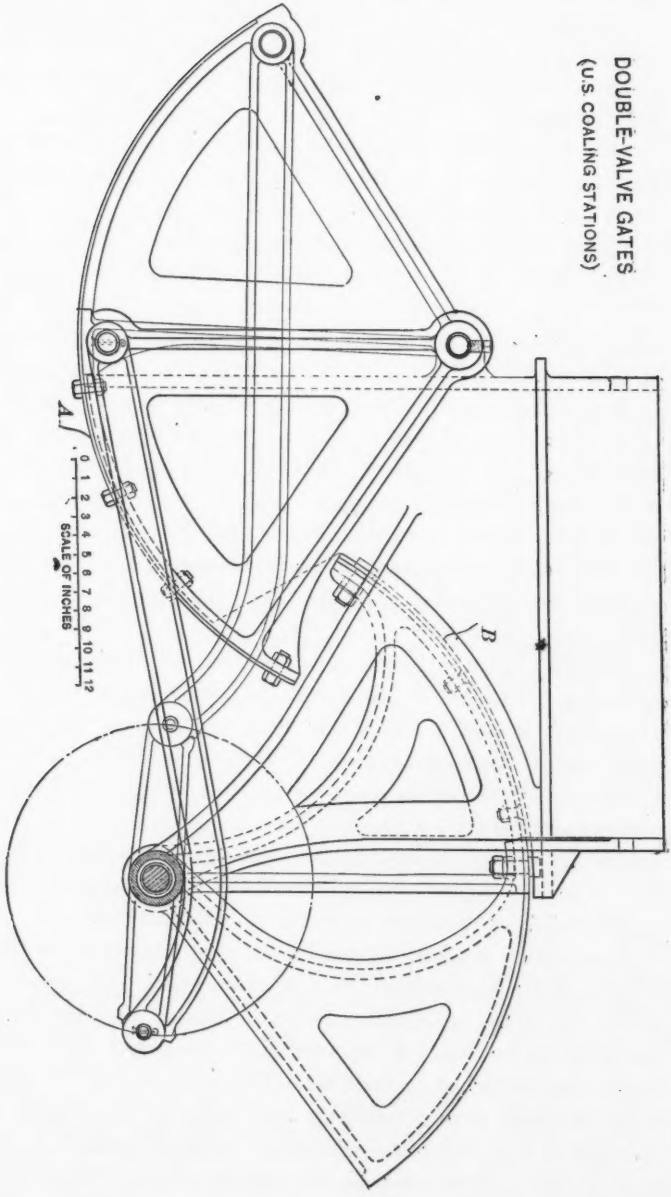

DOUBLE-VALVE GATES
(U.S. COALING STATIONS)
A
B
0 1 2 3 4 5 6 7 8 9 10 11 12
SCALE OF INCHES

Fig. 2.

a lump to get between them and prevent their closing, nor does the gate have to be geared with sufficient strength to bite through a lump of coal, which would necessarily have required a very slow movement.

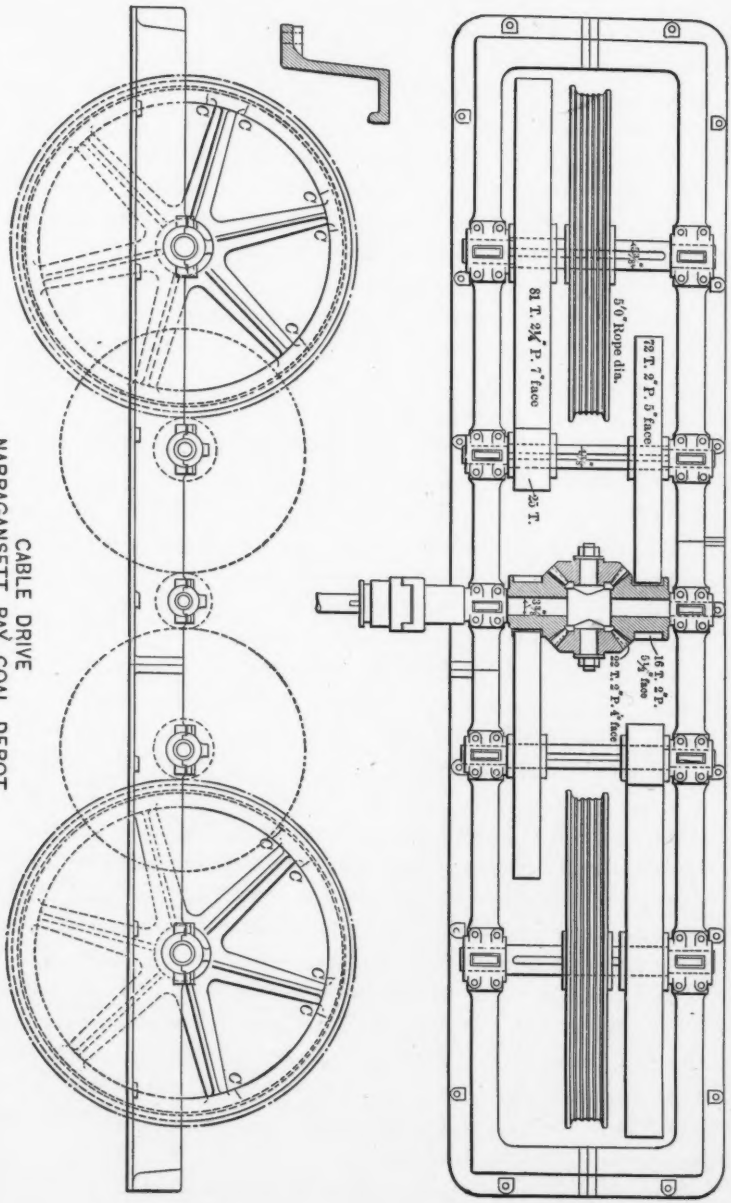
The edges of the valves of this gate miss each other by about 9 in., and there is no trouble in handling lumps of bituminous coal after the men have learned the tricks of the gate.

Each valve of the gate is worked by a separate lever—one controlled by the left hand and the other by the right hand of the operator. To draw coal, Valve *A* is opened before Valve *B*. To shut off, *B* is closed before *A*. The crank and connecting rod controlling *A* pass over a dead center in both positions, so that the valve may be held automatically either open or shut. Valve *B* remains either open or shut by virtue of its weight. The gate works easily, and the head of coal on it appears to make no difference, except that *B* cannot be opened until *A* is opened and the coal commences to flow, when the pressure on *B* seems to be entirely released. The levers are removable, so that the gates cannot be opened by mischievous persons unless equipped with proper tools. This gate is believed to be new.

Since the station has been turned over to the Government, its operation, in the main, has been satisfactory, except perhaps that the towers are rather unwieldy and the delivery trestle on the wharf might have been higher, as mentioned previously.

The trestle, however, seems to be high enough for loading the colliers and barges for which it was designed, and on a recent occasion the Collier *Caesar,* detailed to assist in towing the dry dock *Dewey* to Manila, was loaded with 2 869 tons of coal in 15 hours, and sailed from the depot 25 hours after her arrival.

The station has been in continuous service since about May 1st, 1904, and the repairs have been inconsiderable. The most serious break was in the cable driver shown by Fig. 3. In July, 1905, both the drums were found to be cracked at the points, *CC,* where the spokes were attached to the rims. The cable road at the time was working under a very moderate load. The cause of these cracks was not at first apparent. Shrinking strains; crystallization; unequal wear of the grooves, causing the winding of the cable to set up an excessive pull between the shafts, on the principle of the differential pulley block; careless or malicious blows of a sledge, were




CABLE DRIVE
NARRAGANSETT BAY COAL DEPOT

Fig. 3.

all considered and set aside. It was finally decided that the cracking was due to the key forcing the drum out of concentricity with the shaft to the amount that it was bored larger than the shaft—namely, about $\frac{1}{64}$ in., so that the drums revolved as cams instead of as true cylinders. The differential gearing allowed one drum to advance or retreat angularly with respect to the other, so that it was quite possible that one cam would be frequently in opposition to the other, causing four parts of $\frac{7}{8}$-in. steel rope to put too great a strain on the arched rim of the six-spoke drum.

A description of the Narragansett Bay Coal Depot would be incomplete without mentioning the water-works installed by the Bureau of Equipment, though the writer had nothing to do with this part of the work.

Fig. 4 shows the general location and arrangement of the water-works system. *A* is a concrete dam, impounding about 3 000 000 gal. of water, the top of the spillway being at Elevation 40 above mean low water. *B* is a duplex hydraulic ram driven by a 12-in. power pipe running from the dam at *C*, which impounds a comparatively small volume of water at Elevation + 81. *D* is a 275 000-gal. stand-pipe, filled by an 8-in. pipe from the ram. The remainder of the water wastes into the lower reservoir. The bottom of the stand-pipe is at Elevation 93 above mean low water. It is 30 ft. in diameter and 52 ft. high. *E* is an 8-in. cast-iron pipe, supplying the fire hydrants and water supply system at the station.

By suitable valves at *F*, water can be drawn either from the stand-pipe under the full head, or from the main reservoir under a head of about 40 ft. The lower head is ample for supplying water to ships and for similar purposes, but, on account of the fire risk, the full pressure of the stand-pipe is usually carried in the main. This pressure is sufficient to throw a stream from a $2\frac{1}{2}$-in. hose over one of the storage buildings.

It is obvious that a fleet of several vessels could not be coaled satisfactorily by lying alongside the wharf at such a station as has been described, even if the captains had no objection to having huge tubs of coal dangling over the decks, for the reason that only one vessel could lie alongside the wharf at one time, and it would be necessary to allow at least one day for coaling each ship.

For fleet or squadron service, the Bureau of Equipment has provided twelve barges, which can be readily loaded from the tres-

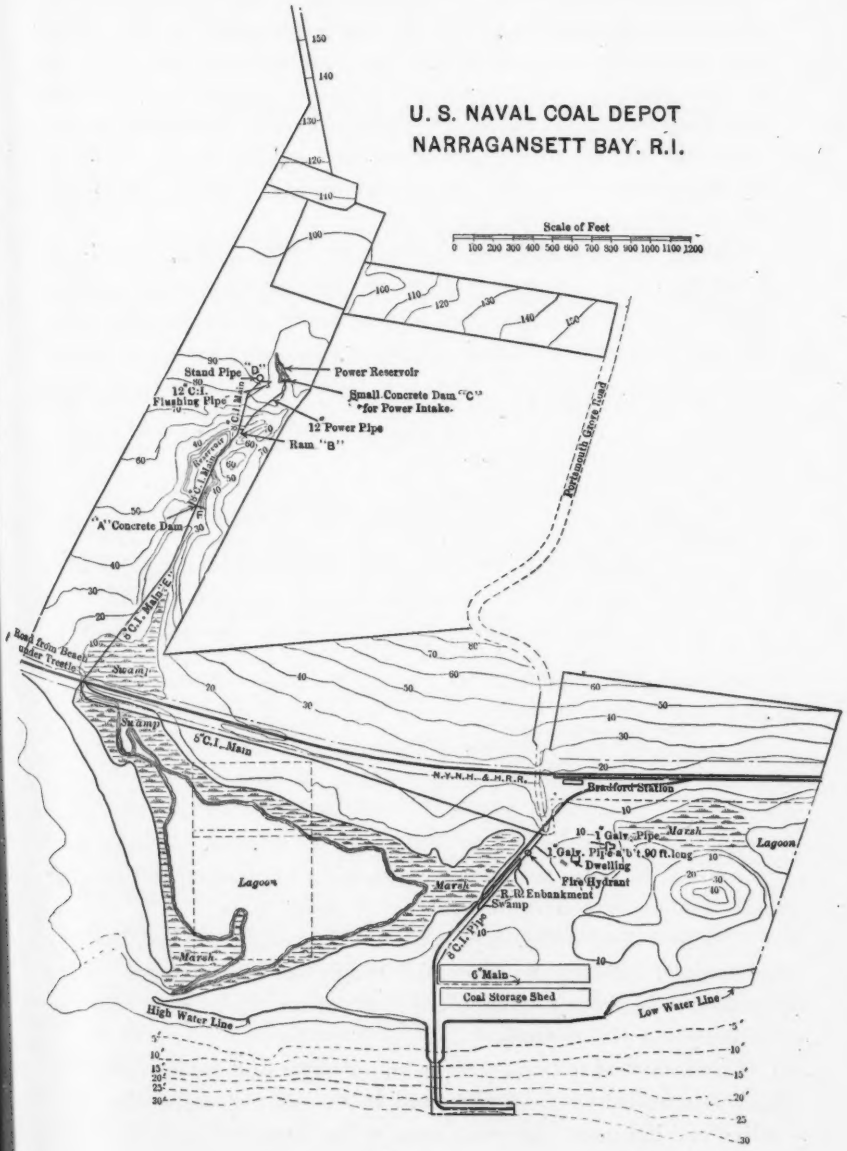

U. S. NAVAL COAL DEPOT
NARRAGANSETT BAY. R.I.
Scale of Feet
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
Stand Pipe "D"
12" C.I. Flushing Pipe
Power Reservoir
Small Concrete Dam "C" for Power Intake.
12" Power Pipe
Ram "B"
"A" Concrete Dam
8" C.I. Main
Portsmouth Grove Road
Road from Beach under Trestle
Swamp
Swamp
8" C.I. Main
N.Y.N.H. & H.R.R.
Bradford Station
1" Galv. Pipe
Marsh
Lagoon
1" Galv. Pipe s'b't 90 ft. long
Dwelling
Fire Hydrant
R.R. Enbankment
Swamp
Lagoon
Marsh
8" C.I. Pipe
6" Main
Coal Storage Shed
High Water Line
Low Water Line

FIG. 4.

tle, and, as a matter of fact, these are kept loaded ready to be taken alongside a war ship needing coal at a few minutes' notice. With such an auxiliary fleet of barges, the ships of a squadron could lie at their moorings, without coming alongside the station, and take coal from the barges quite as rapidly as if they were immediately under the coaling appliances. More manual labor is required with the barge system, but there are usually men enough on Naval vessels to minimize this disadvantage.

Water barges and a tug have recently been added to the auxiliary fleet, and to protect these the Bureau has since constructed a granite breakwater, shown by Fig. 5, on substantially the same general specifications as adopted for the nine piers of the main wharf,

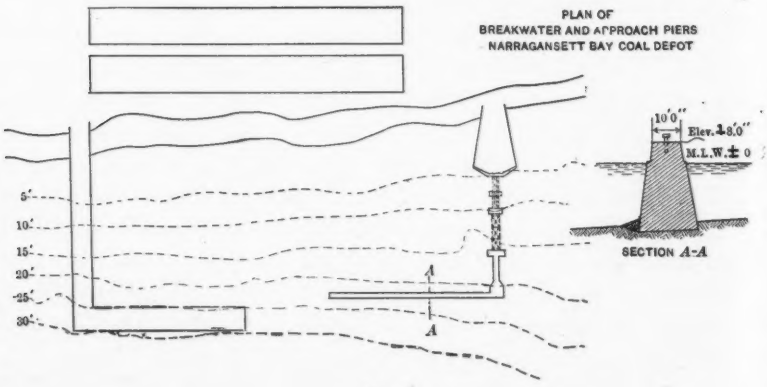



FIG. 5.

except that it was decided to dredge for the footing course of the breakwater, in order to avoid any possibility of unequal settlement, and eliminate settlement altogether, if possible.

The custodian of the depot is a trained man of the Navy, having the rank of Boatswain. The other employees are civilians. The usual force is about 15 men, some of whom are working as laborers in improving the grounds.

Comfortable dwellings, with running water and modern plumbing, are provided by the Government on the reservation for the custodian and the more important men in his force.

An electric-light plant is now being installed, so that the station will soon be available for night as well as for day work.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## FOUNTAIN FLOW OF WATER IN VERTICAL PIPES.

By Messrs. F. E. Lawrence and P. L. Braunworth.

To be Presented October 17th, 1906.

### Introductory.

The purpose of the experiments described in this paper was to obtain a general law for the fountain flow of water from vertical pipes, for pipes of any size and for any head over the crest.

It has long been an accepted theory, supported by demonstration in physical laboratories, that the height of a jet of water equals nearly $\frac{V^2}{2g}$, the difference being supposed to be due to air resistance; but the theory does not take into consideration the weight of the column of water and the fact that the condition of flow for high heads is entirely different from that for low heads.

For very low heads the flow is almost identically the same as the flow over a sharp-crested weir. In both cases, the water flows over the edge in a smooth sheet. If there is a vacuum beneath the sheet, it clings to the weir in both cases; and if air is admitted, the sheets jump free.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

In passing from the quiet sheet flow to the jet, the flow is of a peculiar character. It begins with a swirling or rotary motion, and ends in a bubbling condition. Just when the jet is finally formed cannot be detected by the eye, as the water in falling hides the jet column.

The results of the experiments to be described give definite information, which confirms very closely the theory of jet flow for high heads, and indicates a law that differs materially from this theory for low heads. Also, the nature of the transition from one condition to the other has been clearly defined, and definite laws have been determined giving, for pipes of any size, the head at which this intermediate stage begins and ends.

That these laws of flow are of considerable importance is patent to all who have tried to determine the flow from fountain influents to filter plants, or from artesian wells. The flow in these cases is most often in the condition where the jet formula does not apply.

As far as the writers know, there has been no previous attempt to determine these laws of flow by experiment, so that they would be generally applicable to pipes of any size. Professor G. E. Todd, State Geologist of South Dakota, has computed a table* on the theoretical jet formula, which does not take into consideration the weir and intermediate conditions. As will appear later, the use of this formula involves very great errors for low heads, giving entirely misleading results, and making the formula worse than useless for these cases.

The United States Geological Survey has for some time tried to obtain experimental data in order to establish these laws of flow, and in the spring of 1905 corresponded with E. W. Schoder, Jun. Am. Soc. C. E., in charge of the Experimental Hydraulic Department of Cornell University, regarding the performance of such experiments. Shortly afterward Messrs. Elliot and Porter took up the matter for a graduating thesis; but, on account of the small head of water obtainable in the basement of the civil engineering building, only the weir condition on one pipe (4-in.) was investigated. One valuable result, however, was brought out in this experiment. It was found that a pressure tap in the side of the vertical pipe was

* "The Motions of Underground Waters," by Charles S. Slichter, U. S. Geological Survey, Water Supply and Irrigation Paper No. 67.

4-IN. PIPE.

PLATE XLII.
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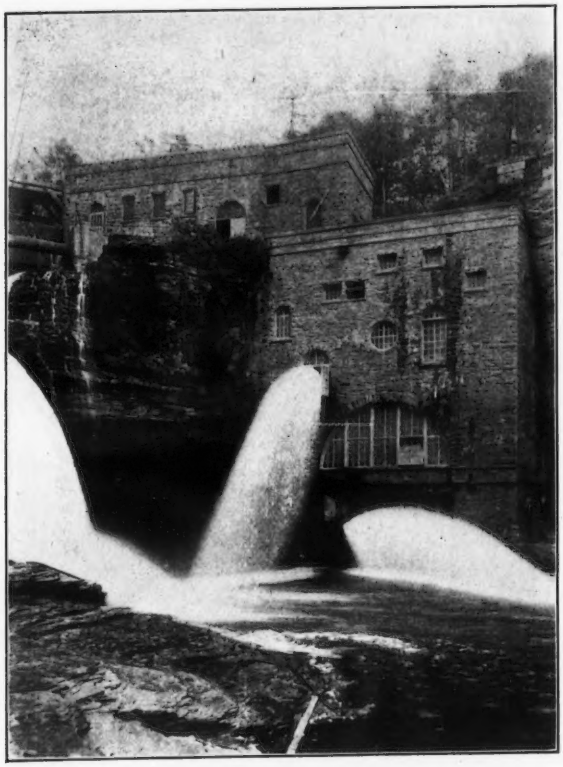


FIG. 1.—HYDRAULIC LABORATORY OF CORNELL UNIVERSITY.

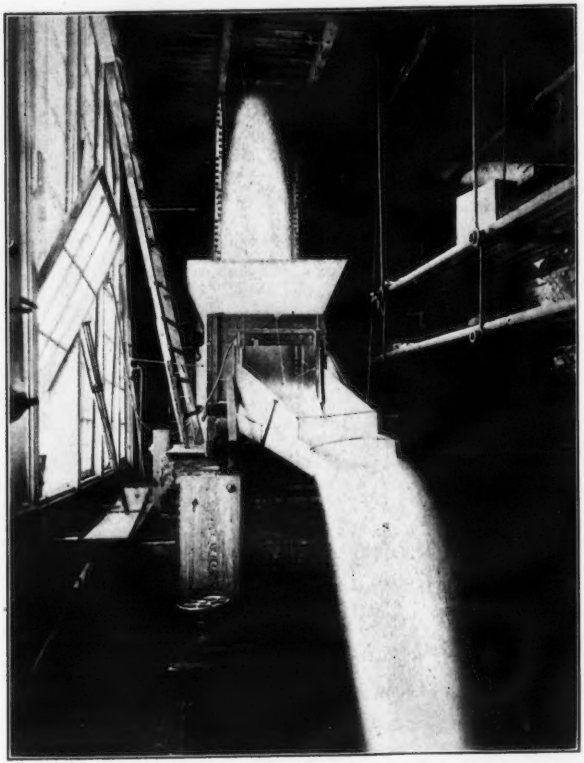


FIG. 2.—APPARATUS DURING A RUN ON A HIGH HEAD, WITH A 4-IN. PIPE.

entirely inadequate for indicating heads. A Pitot tube gave far better results.

In the early spring of 1905, the writers determined to spend the succeeding summer in obtaining experimental data on this subject, using as wide a range of sizes of pipes as possible.

The College of Civil Engineering generously offered to supply the greater part of the equipment needed in the work, and Professor Schoder arranged to make use of the peculiar advantages offered by the Hydraulic Laboratory in Fall Creek Gorge.

The writers feel deeply indebted to Professor Schoder for his valuable advice, and skilful planning and arrangement of the apparatus used. It is to his encouragement and enthusiasm that the successful issue of these experiments is largely due.

The experiments were begun in July and finished in September, 1905, covering a period of seven weeks.

## Description of Apparatus.

*Hydraulic Laboratory.*—The Hydraulic Laboratory of Cornell University is situated in Fall Creek Gorge just below Trip-Hammer Falls. The building encloses a stand-pipe, 6 ft. in diameter and 68 ft. high, which is used as a supply for experimental purposes on the various floors of the building, and receives its supply, either from a 30-in. pipe or from the 16-ft. experimental canal. Both these sources are fed from Beebe Lake, which is just above the falls. The supply is led through baffle boards into a weir chamber, 25 ft. long, and over a sharp-crested weir, into the stand-pipe.

Fig. 1, Plate XLII, is a view of the building, and the general elevation of the stand-pipe and experimental apparatus is shown on Plate XLIV. In Fig. 1, Plate XLII, may be seen the discharge from the 12-in. regulating gate on the second floor, and also from the 36-in. gate at the bottom. The latter gate is operated by a hydraulic lift, and was used to empty the stand-pipe at the end of the day's work.

*Apparatus.*—The apparatus common to all experiments, Plate XLIV, consisted of a 12-in. vertical pipe connected at the bottom to a stand-pipe nozzle by an elbow and a gate-valve. This

pipe supported a large cypress box having a spout. It was arranged so that the flow from the box could fall into the large lead-lined measuring tank, or, by means of a galvanized-iron diverter, could be led clear over the side of the tank and let fall to the concrete floor below, where several drains carried it to the creek.

The 12-in. pipe was of ordinary well-casing, and was fitted at the lower end with a plain flange for bolting to the elbow, and at the upper end with a special flange, which secured water-tightness and at the same time helped to support the box. The box was provided with a flaring galvanized-iron top-piece, 1 ft. 7 in. high. This was fitted into the top of the box, and served to prevent loss of water during high-head runs.

The trough diverter was provided with extension sides in order to carry off the higher heads and also prevent splashing. The upper end was given a slope of 45° so as to form a good cutting edge when pushed through the stream of water. The latter arrangement made it possible to cut off the supply instantly. The diverter in operation, wasting the flow from the 4-in. fountain, with a head of about 8 ft., is shown in Fig. 2, Plate XLII.

*Arrangement of Pipes.*—The pipes used in these experiments were 12, 9, 6, 4 and 2-in., giving, in the writers' opinion, a sufficiently wide range. It was also thought that the experiments could be made more valuable by using pipes of the sizes used in actual practice.

TABLE I.—Dimensions of Pipes.

| Length, in Feet. | | Diameter, in Inches. | | Thickness, in inches. | Position of Pitot tube insertion below top, in inches. |
|---|---|---|---|---|---|
| Weir part, in feet. | Stem part, in feet. | Nominal. | Measured and accepted. | | |
| 2.70 | 6.00 | 2 | 2.080 | 0.10 | 1.90 |
| 3.10 | 9.65 | 4 | 4.090 | 0.14 | 4.00 |
| 3.05 | 10.85 | 6 | 6.197 | 0.19 | 6.20 |
| 2.83 | 11.90 | 9 | 9.172 | 0.22 | 9.20 |
| 2.99 | 12.00 | 12 | 12.586 | 0.16 | 12.66 |

In the descriptions following, the nominal, instead of the actual, diameters are used.

The total length of these pipes varied from 12 to 15 ft., which length helped to restore the abnormal conditions of flow, caused

VERTICAL SECTIONS THROUGH CENTER LINES

Fig. 1.

ARRANGEMENT OF PIPES FOR FOUNTAIN-FLOW EXPERIMENTS

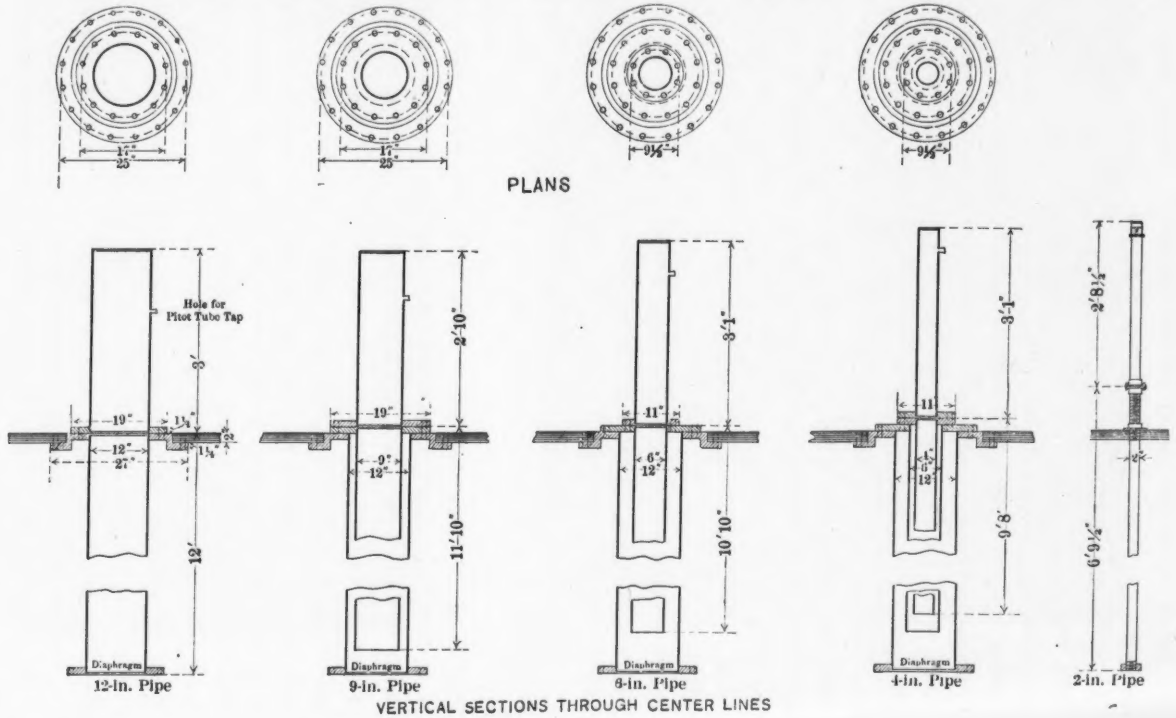



FIG. 1.

by the elbow, to more nearly normal conditions, at the top. The 12-in. pipe was of well-casing, and the 9, 6 and 4-in. pipe of standard wrought iron. The 2-in. pipe was of seamless drawn brass.

Fig. 1 shows the arrangement of the pipes. Each pipe was composed of two parts, the upper or weir length, and the lower or stem. The stems had flanges so as to fit the large flange of the 12-in. pipe when lowered into place. This arrangement was made for the convenience of leaving the stems in place, which was done in all cases except for the 9-in. pipe. The weir lengths and their flanges were the only parts removed. The tops of these lengths were turned true in a lathe, both inside and outside, to a depth of about 6 in., and the upper edge was beveled off on the outside at an angle of 60° with the horizontal, thus giving in effect a sharp-crested weir. At a distance from the top, equal to the diameter of the pipe, a tap was made for the attachment of the Pitot tube sheath.

After cleaning off the rust, four measurements of diameters were made with steel calipers near the upper edge of the weir.

The 2-in. combination was fitted up after the experiments had been made with all the other pipes. For this the weir length of the 4-in. pipe was removed and a blank flange put over the top of the 4-in. stem. Then the 2-in. stem was fitted to the elbow from the 6-in. gate on the stand-pipe (Plate XLIV). This stem, when put through a hole in the box, projected a short distance above the floor. A collar, serving as a lock-nut, was then screwed down over the stem. This prevented leakage. The 2-in. weir length was made up of two pieces, the top being made specially for the purpose.

In order that the experiments might be made under conditions of flow as nearly normal as possible, the effect of the 12-in. elbow had to be compensated. This was done with a galvanized-iron diaphragm, placed between the top flange of the elbow and the bottom flange of the 12-in. pipe. This was arranged to provide resistance to the water leaving the convex side of the elbow, and free flow to the slower moving water from the concave side (Fig. 2).

It was thought that this would produce nearly normal flow above the elbow. That this proved to be correct is shown by

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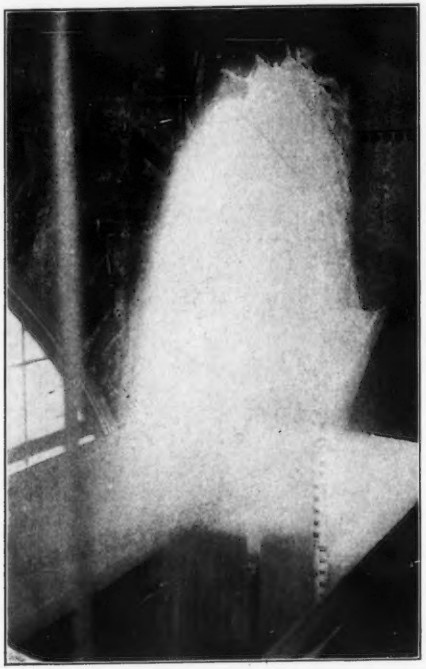


FIG 1.—HIGH JET FROM 2-IN. PIPE.

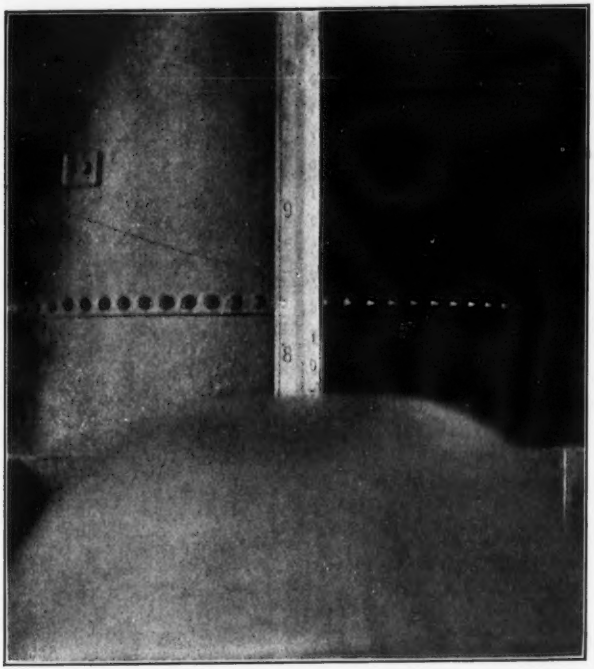


FIG. 2.—WEIR CONDITION ON 12-IN. PIPE.

Plates XLV and XLVI, the velocity traverses taken by the Pitot tube.

*Pitot Tube.*—The Pitot tube used for measuring heads above the crest of the pipe, is shown in section with the sheath in Fig. 3.

The tube proper consists of a straight cylindrical brass tube, having an external diameter of 0.17 in. and an internal diameter of 0.10 in., being 9.6 in. long, and closed at the lower end. The

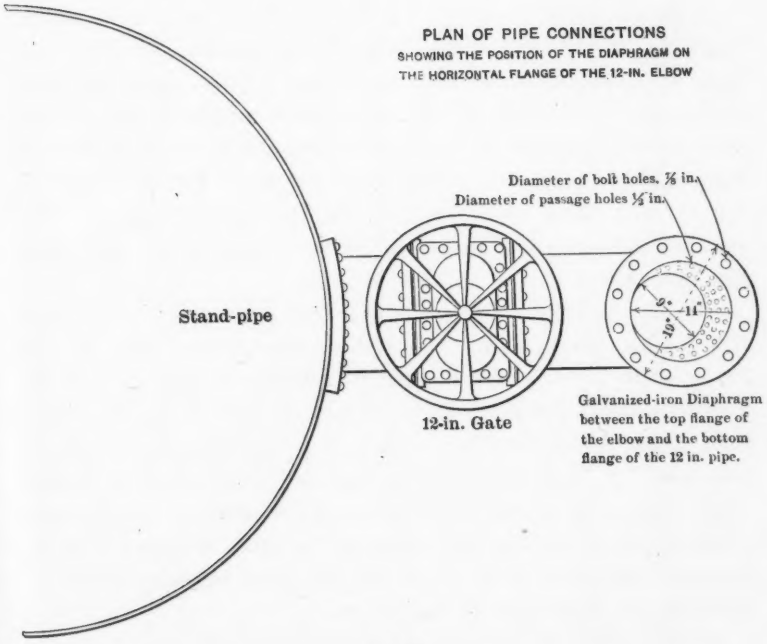



FIG. 2.

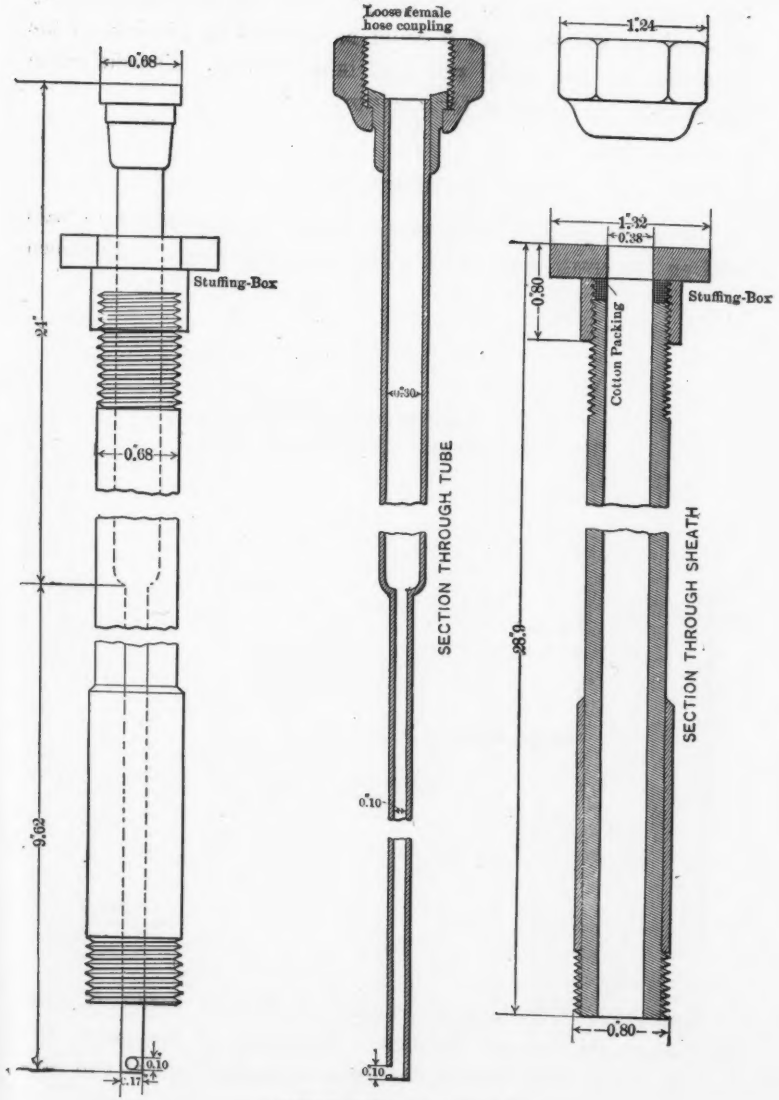
impact opening is a hole, 0.10 in. in diameter, drilled at right angles to the axis of the tube and 0.10 in. from the end. At the outer end the tube widens out to a diameter of 0.30 in., so as to slide snugly through the stuffing-box at the end of the sheath. Near the end of the tube is a pointer for indicating the direction of the impact opening. The sheath screws into the hole drilled through the pipe wall. The burr inside the pipe, made by the drill, was carefully filed off. When the sheath was screwed into the hole,

care was taken that it did not extend into the pipe. The other end of the tube has a female coupling, to which the hose was attached. The hose was connected with one arm of a glass gauge, mounted on a wooden frame, on which was a scale graduated in feet and hundredths. By opening the stop-cock at the top of the gauge, the arm was used as an open column. As the gauge was only 2 ft. high, it had to be raised when the head exceeded this amount. Several changes were necessary for the smaller pipes.

*Sighting Rods.*—In order that the results of these experiments might be put into use in the field, where the Pitot tube is not always available, sighting rods were used. These were ordinary stadia rods, blocked off in red and white to tenths of feet. They were placed vertically in opposite corners of the box, so that a sight might be taken over the center of the pipe. They were leveled up, so as to give equal readings for the same elevation. The sighting rods were not used until after the runs on the 9-in. pipe had been made.

*Measuring Tank.*—The measuring tank is of 4-in. pine, and is lined with sheet lead. Its inside dimensions are: 15 ft. 10 in. by 10 ft. by 5 ft. 5 in., and its capacity is about 850 cu. ft. Two tape blocks and boxes were fastened securely to the top of the tank on opposite sides. Steel tapes carrying long-pointed plumb-bobs were run over the blocks and fastened to spools in the boxes. These tapes were graduated in feet and hundredths. On the tops of the blocks were brass plates, grooved to allow the tapes to slide through. Readings were made on the tapes opposite reference scratches on either side of the groove.

*Rating.*—In order to measure the quantity of water during a run, the measuring tank was rated in the following manner: The readings on the tape for the bottom of the tank were first taken. Then 5 cu. ft. of water was weighed out in a galvanized-iron tank on a small Fairbanks scale, and emptied into the large measuring tank. When five of these had been poured in and the water quieted, the tapes were read again. Readings were taken by lowering the plumb-bobs until their points just touched the water surface. For the remainder of the rating, readings were made for every 50 cu. ft. Plottings were then made showing the relation be-




PITOT TUBE AND SHEATH

FIG. 3.

tween the tape readings and the quantities for each tape. This was practically a straight line in each case. Then, if the quantity for any run was required, it could be obtained by picking off the quantities for the initial and final tape readings. The difference represented the quantity for the run.

## Experimentation.

The readings on the Pitot-tube gauge, corresponding to zero head on the crest, were found in the following manner: As shown

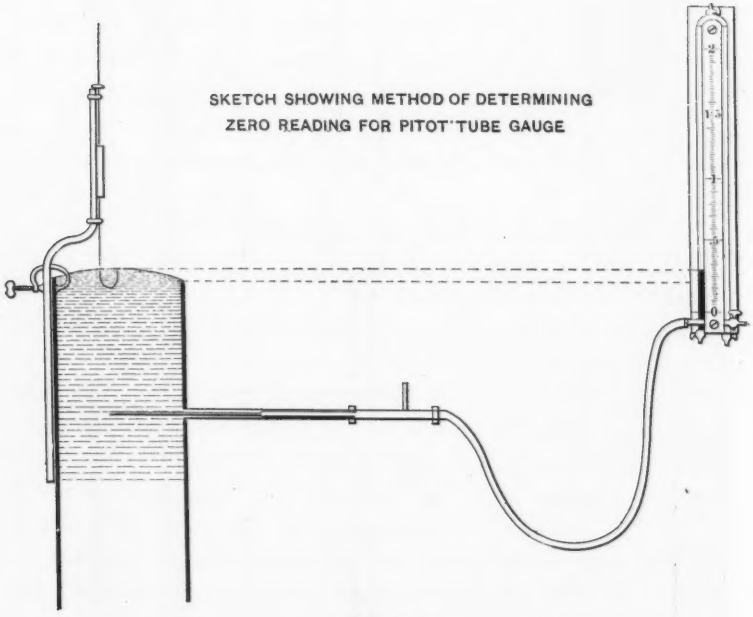
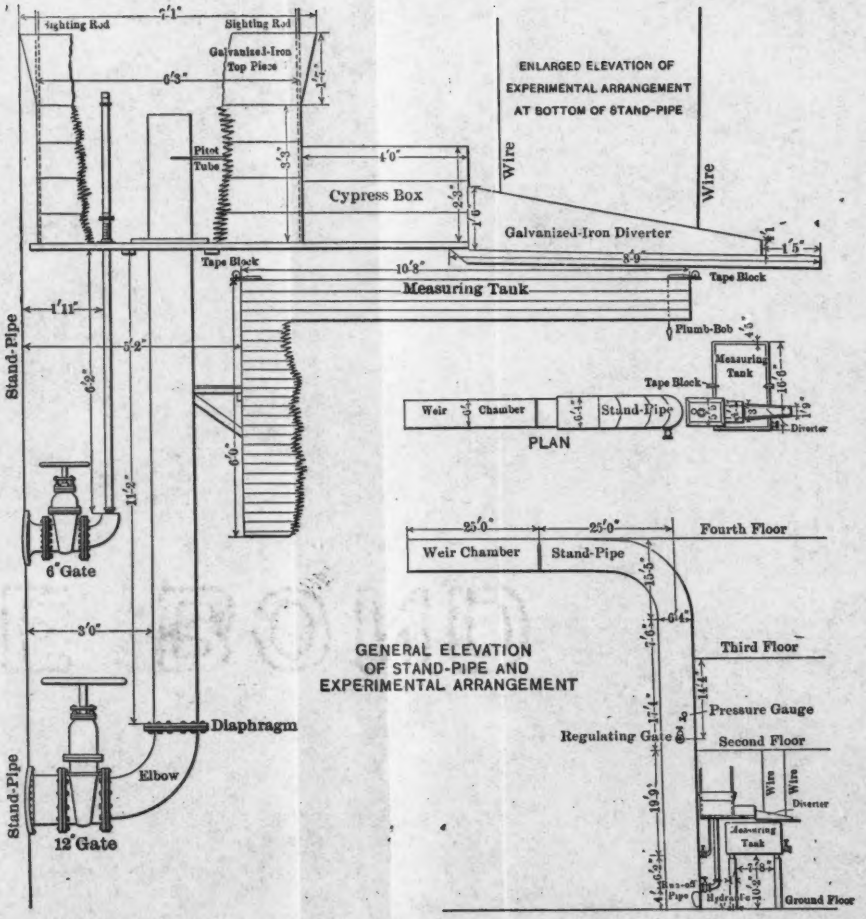



Fig. 4.

in the sketch, Fig. 4, a hook-gauge, reading to 0.0001 ft., was clamped to the side of the pipe. The point of the gauge was brought to the exact level of the crest by supporting one end of a small spirit-level on the point of the hook-gauge, with the other end resting on the edge of the pipe, along a diameter which was previously found to be level. The readings were made when the

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bubble came to the center. Water was then let into the pipe until it was full. Then the gate was closed, but, owing to a small leakage in the valve, there was a very slight overflow. Several settings for the water surface level were made with the hook-gauge, and simultaneous readings were taken on the glass-gauge. The glass-gauge was read by placing the upper edge of a small brass runner tangent to the bottom of the meniscus of the water column, and reading on the scale alongside. The difference of the average of the two sets of hook-gauge readings, subtracted from the average of the glass-gauge readings, gave the zero reading of the glass-gauge referred to the crest level. This determination of the zero reading was made several times for each pipe, because the deduced heads depend largely upon it for their accuracy.

It was of considerable importance to keep the hose connection of the Pitot tube entirely free from air. When air gets into the tube, the readings on the gauge are either too high or too low, but usually the latter. To prevent air from accumulating in the bends, the hose was frequently shaken out. By sucking on one opening of the gauge a siphon was formed and the air brought out. In one case a small hand-pump was used to good advantage.

In order to prevent the pounding of water in the stand-pipe, and the consequent formation of air bubbles, it was necessary to keep the stand-pipe full at all times; but, as the quantity taken out for experimental purposes varied, and was usually smaller than that taken in over the standard weir, the 12-in. regulating gate on the second floor was used. This gate discharged the water outside the building, as shown in Fig. 1, Plate XLII. Alongside this gate a steam-gauge was connected to the stand-pipe. A few trials showed the pressure for which the stand-pipe became full.

In order to secure a steady head, the method of operation was, first, to adjust the 12-in regulating gate until the head indicated by the steam-gauge was nearly constant. Then the required head, as shown by the Pitot tube, was set by the 12-in. gate at the bottom of the experimental pipe. Finally, the level of the water in the stand-pipe was readjusted by the regulating gate, until the head was absolutely steady. In this way a uniform flow was assured

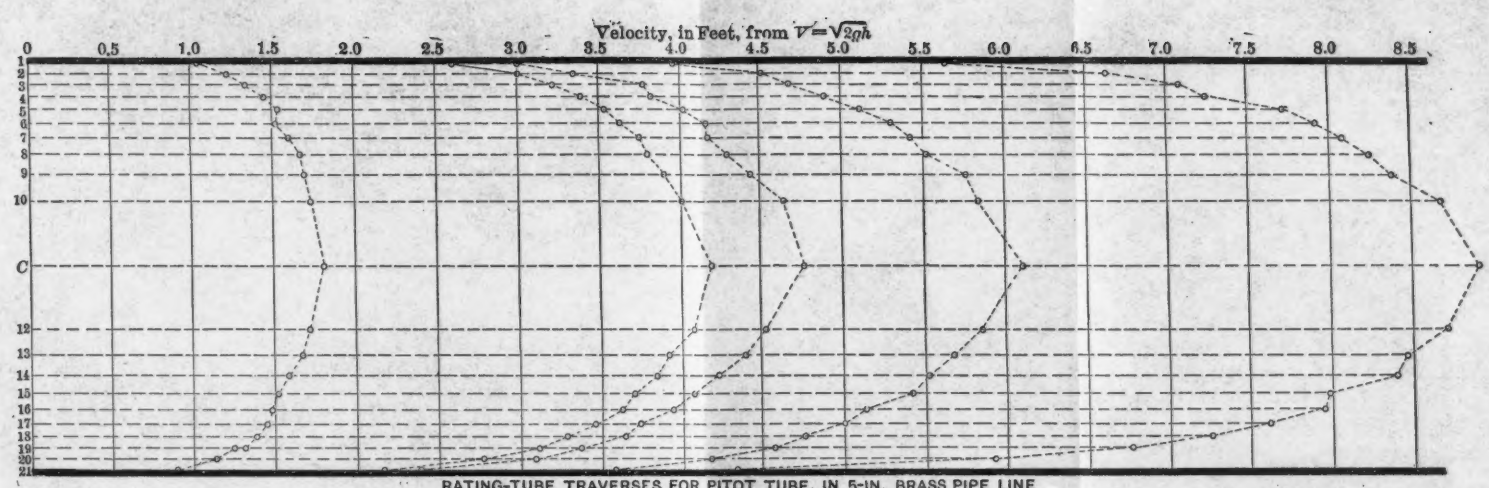
in the experimental pipe. At first, this adjustment took considerable time, but later it was made more quickly.

*Method of Experimentation.*—In making a run, the procedure was as follows: The Pitot tube was set with the impact opening directed vertically downward at the center of the pipe. The setting was done with a stick, on which was a mark placed so that when the end of the stick was held against the pipe under the tube sheath, and the edge of the indicator was brought over the mark, the impact opening of the tube was then on center. The direction of the impact hole of the tube was given by the pointer (already described). The air was then shaken out of the hose, and the head adjusted, as previously described.

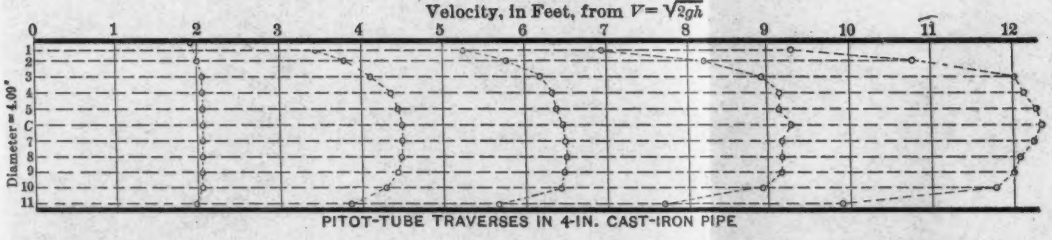
Two readings were made for each tape on the measuring tank, and recorded, unless the differences from the last level in the tank varied more than 0.004 ft., in which case the readings were repeated.

At a given signal, the diverter was swung out and the water allowed to flow into the tank. The initial time was noted by an ordinary well-regulated watch, and recorded. As soon as the run had started, readings on the glass-gauge were taken. The water column vibrated considerably at times, especially for high heads, when the jet would leap up and suddenly drop down, while at other times it remained quite stationary in an intermediate position. The maximum and minimum readings were taken, and especially the point where the jet remained stationary for a short time. During this latter stage a slight trembling was noticed in the gauge column. Usually, six readings were taken. These were distributed so that the final one was near the end of the run. All readings were made on the bottom of the meniscus.

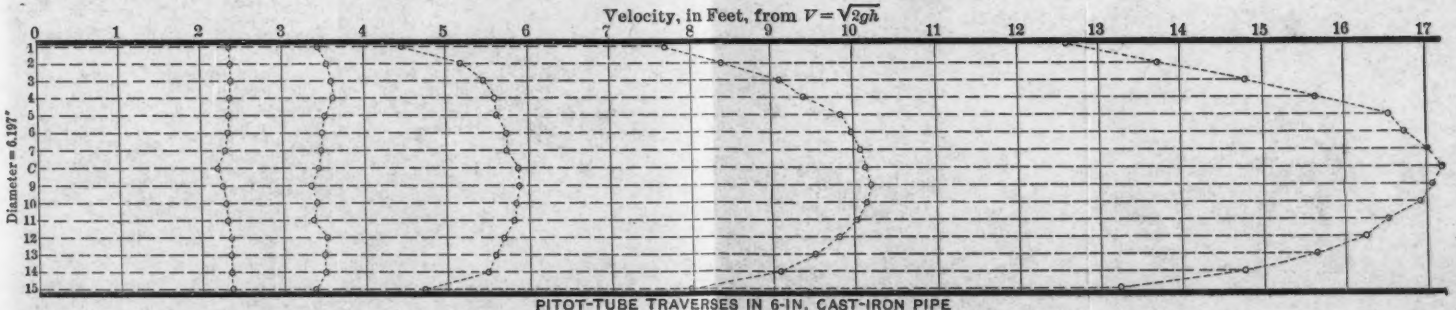
At the same time, observations were made on the sighting rods. This was done by holding the small blade of a knife at some point on the rod and standing off at arm's length. Then, by sighting along the knife to a point of equal reading on the other rod it could be determined whether the knife was too low or too high. The final level was chosen so that the fountain column would remain above it about the same length of time as below, or




RATING-TUBE TRAVERSES FOR PITOT TUBE, IN 5-IN. BRASS PIPE LINE




PITOT-TUBE TRAVERSES IN 4-IN. CAST-IRON PIPE




PITOT-TUBE TRAVERSES IN 6-IN. CAST-IRON PIPE

that a short, high leap would compensate for a smaller depression, but of longer duration.

One observation was made by each of the two observers for each head. The results were not announced until both had been made. Thus the observations were independent, which tended to eliminate the personal equation.

When the last gauge reading was made for Pitot tube on center, the tube was pulled out of the pipe 3 in. back into the sheath so as to indicate the wall pressure. The indication of the gauge for this position of the tube is evidently the same as for a simple piezometer in the side of the pipe. The Pitot tube here merely serves in place of a hose connection to transmit the pressure to the gauge, from the sheath, which corresponds to a piezometer tap. These readings, when corrected for the zero of the Pitot-tube gauge, give what are called "Pressure Heads" in Table 3. Two readings were made for each head. On the second signal, the diverter was pushed back into place, and the water was wasted over the side of the tank. The time was again noted.

The cutting edge of the diverter (Plate XLIV) was made so that very little water was lost by splashing. Wooden guides along the side secured a sure return to the exact place.

While waiting for the water in the tank to quiet, another head was adjusted, which saved considerable time. The tapes were then read, as before, and another run started, unless the tank was full, in which case it was emptied by means of an 8-in. gate near the bottom. Enough water was left in to cover the bottom completely, and the tapes were then read again. The durations of the runs varied considerably. For low heads, runs of 25 min. were sometimes made, while for high heads, they were very short, especially with the 12-in. pipe, where, for the highest heads, the large tank was filled in 1 min. During the long runs one of the observers made frequent trips to the regulating gate to be sure that the head was steady, as indicated by the steam-gauge.

As the original notes fill one and one-half ordinary transit books, it was thought best to give herein only a sample form of notes. The original notes will be kept on record in the College of Civil Engineering, Cornell University.

SAMPLE FORM OF NOTES.

Runs for 4-in. pipe. Sept. 20th, 1905.

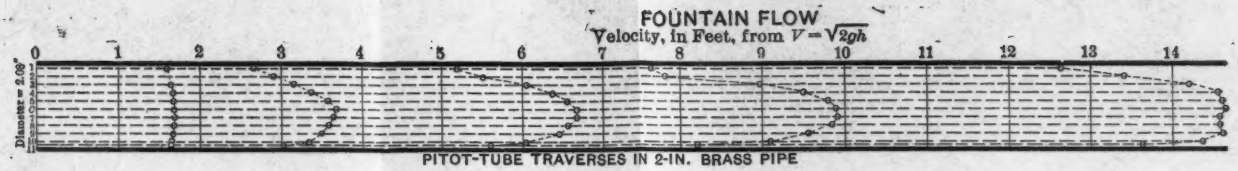
Zero of gauge = 0.231. Zero of rods = 3.17.

| | Pitot-tube gauge. | Time. | Tapes. | | Sighting rods. | Gauge reading for pressure. |
|---|---|---|---|---|---|---|
| | | | No. 1. | No. 3. | | |
| Initial..... | 1.580 | 11:34:45 | 6.940 | 26.959 | 4.48 | 0.296 |
| | 1.445 | ..... | 6.940 | 26.960 | ..... | 0.283 |
| | 1.530 | ..... | ..... | ..... | ..... | ..... |
| Final..... | 1.550 | 11:37:15 | 7.709 | 27.730 | 4.45 | 0.285 |
| | 1.475 | ..... | 7.710 | 27.730 | ..... | ..... |

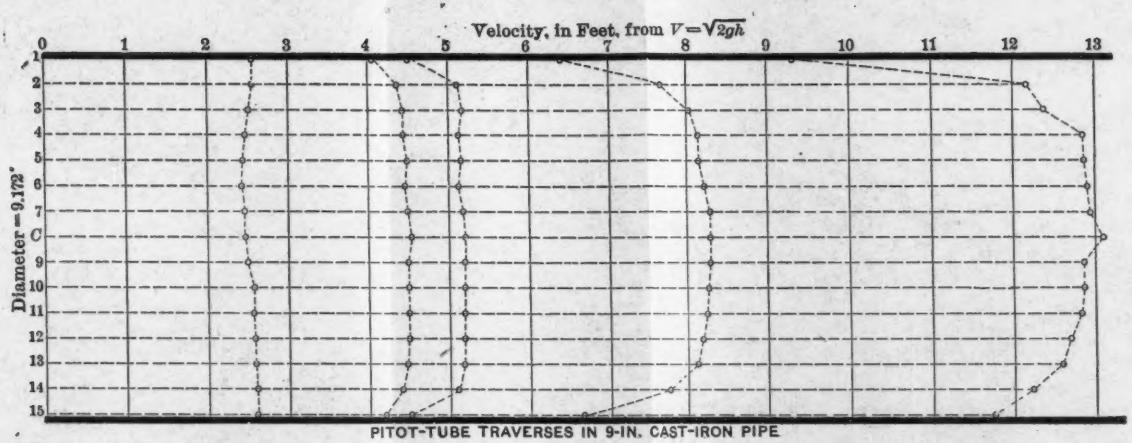
*Pitot-Tube Traverses.*—Five Pitot-tube velocity traverses, Plates XLV and XLVI, at as many different heads, were made on each pipe, and distributed so as to show the character of the flow at the various heads. A stick was made (the same as for adjusting the Pitot tube on center) on which the diameter was laid off and divided into 15 equal parts, giving 16 points (except in the case of the 2 and 4-in. pipe, where 11 points were used). By placing the end of a stick against the pipe, under the tube sheath, any point along the diameter could be set from the edge of the pointer on the tube.

After adjusting the head as for the runs, the head on center was first read, three readings usually being taken. Then three readings were taken on the other points, from 1 to 16, and finally at the center again. The plottings (Plates XLV and XLVI) were made by using velocities from the formula, $V = \sqrt{2\,gh}$, and distances along the diameter.

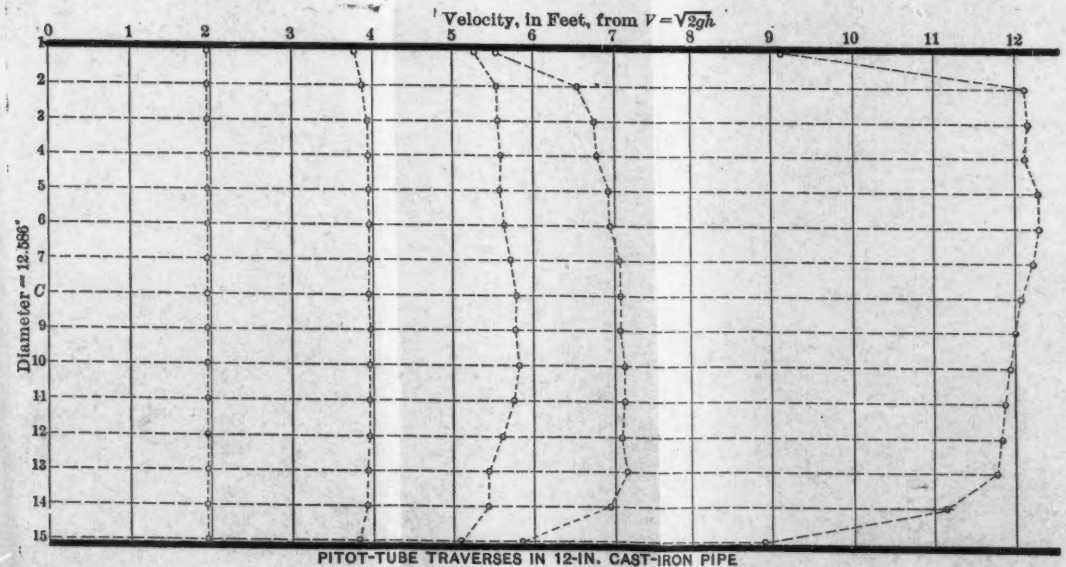
As explained previously, the diaphragm was placed at the position on the elbow where the water assumed a vertical flow, namely, on the horizontal flange of the elbow, so that a more even distribution of velocities across the pipe would result. The long vertical length of pipe was used in order to give greater facility to the water in regaining its natural flow by the time it reached the crest of the pipe. It is apparent, therefore, that, to obtain the actual distribution of velocities, it was necessary to take points across the pipe, beginning at a point farthest away from the standpipe and running across to the nearest position (Plate XLIV);




PITOT-TUBE TRAVERSES IN 2-IN. BRASS PIPE




PITOT-TUBE TRAVERSES IN 9-IN. CAST-IRON PIPE




PITOT-TUBE TRAVERSES IN 12-IN. CAST-IRON PIPE

in other words, in a line parallel to the flow of water from the stand-pipe to the vertical pipe, and hence parallel to the horizontal length of the elbow.

The traverse plottings (Plates XLV and XLVI) show a remarkably good distribution.

*Rating Traverses.*—In order to determine the tube coefficient, it was rated near the lower end of a 5-in. seamless drawn-brass pipe, 120 ft. long, leading directly from Beebe Lake and discharging into a concrete measuring tank of 500 cu. ft. capacity. These were made in co-operation with Mr. T. J. Rodhouse,* who was making an extensive series of tests on various Pitot tubes for the degree of M. C. E., and who, with Mr. C. Berry, was rating a great many tubes for the Ontario Power Company. These two men generously aided in the ratings, so that the writers feel that they are very reliable.

The cross-section of the pipe was divided into ten concentric rings of equal area, giving, with the center point, 21 points on a diameter. This method of dividing the area makes the calculation of mean velocity very easy by using the formula,

$$V_m = \left\{ \frac{(V_1 + V_{21}}{2} + V_2 + V_3 + \ldots + V_{20} \right\}$$

Wall pressures were taken from a tap in the same cross-section plane as the Pitot tube, and were connected to one arm of a water differential gauge, while the Pitot tube was connected to the other arm. The difference between the two column readings gave the velocity head, which was converted into velocity by the formula, $V = \sqrt{2gh}$.

While readings were being made on the gauges, several runs into the measuring tank were made for quantity. The average quantity, in cubic feet per second, during a traverse, divided by the area of the pipe section, gave the mean velocity, $U$ (or actual), by tank measurement. The mean velocity, $V_m$, by the Pitot tube was computed from the foregoing formula, and, finally, the tube coefficient, $\frac{U}{V_m}$, was obtained. This was found to be 1.005 for the mean of five traverses, as shown in Table 2, This is very near unity, and, for all practical purposes, may be taken as such.

* See Thesis by Mr. T. J. Rodhouse: Cornell College of Civil Engineering, 1905.

TABLE 2.—PITOT-TUBE RATING IN 5-IN. BRASS PIPE LINE.

| Number of Traverse. | $U$ | $V_m$ | $\frac{U}{V_m}$ | $V_c$ | $\frac{V_m}{V_c}$ | $\frac{U}{V_c}$ |
|---|---|---|---|---|---|---|
| 1 | 5.244 | 5.293 | 0.992 | 6.110 | 0.865 | 0.858 |
| 2 | 4.125 | 3.956 | 1.043 | 4.770 | 0.830 | 0.865 |
| 3 | 7.760 | 7.800 | 0.995 | 8.930 | 0.873 | 0.870 |
| 4 | 3.495 | 3.530 | 0.990 | 4.200 | 0.841 | 0.833 |
| 5 | 1.500 | 1.486 | 1.009 | 1.810 | 0.821 | 0.829 |
| Averages | ..... | ..... | 1.005 | ..... | 0.846 | 0.851 |

TABLE 2.—*Continued.*

ADDITIONAL RUNS WITH PITOT TUBE KEPT ON CENTER.

| Number of Run. | $V_c$ | $U$ | $\frac{U}{V_c}$ |
|---|---|---|---|
| 1 | 10.43 | 9.13 | 0.875 |
| 2 | 9.45 | 8.24 | 0.872 |
| 3 | 7.84 | 6.83 | 0.872 |
| 4 | 6.62 | 5.67 | 0.858 |
| 5 | 4.53 | 3.90 | 0.862 |
| Average | ..... | ..... | 0.868 |

$V_c$ = Velocity of tube at center,
$V_m$ = Mean velocity from traverses,
$U$ = Mean velocity (measured).

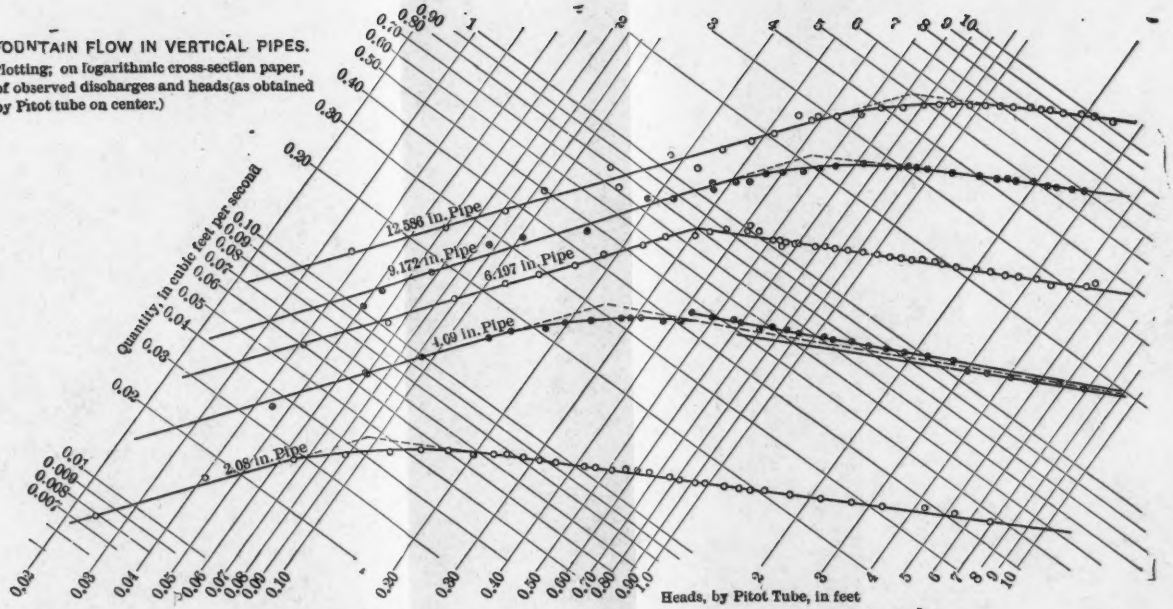
The writers believe that for most work on pipes in actual practice, a simple tube of this form gives results fully as accurate as, if not better than, a great many of the more complex but less durable tubes. The ratio, $\frac{V_m}{V_c}$, averages 0.846, which agrees closely with the results by other observers.*

The writers do not present in detail the numerical data for either set of traverses, as the plottings are sufficiently illustrative. The data, however, will be kept on record in the College of Civil Engineering of Cornell University.

* Paper by Messrs. Williams, Hubbell and Fenkel, with discussion; *Transactions*, Am. Soc. C. E., Vol. XLVII.

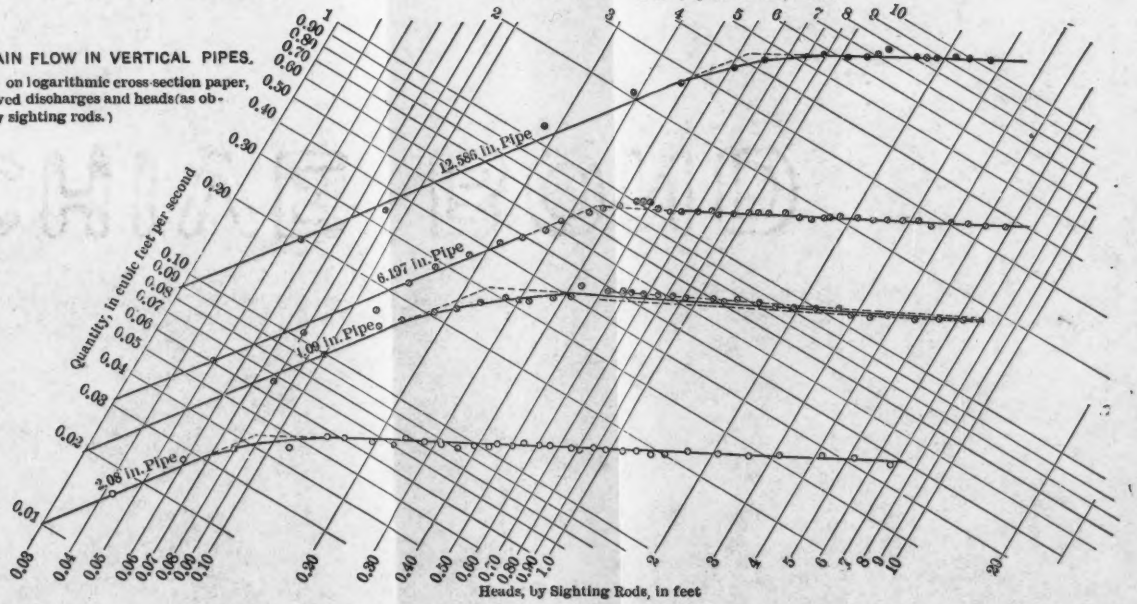
FOUNTAIN FLOW IN VERTICAL PIPES.

Plotting, on logarithmic cross-section paper, of observed discharges and heads (as obtained by Pitot tube on center.)




FOUNTAIN FLOW IN VERTICAL PIPES.

Plotting, on logarithmic cross-section paper, of observed discharges and heads (as obtained by sighting rods.)



## Reduction of Observations and Results.

*Computations.*—The averages of the heads, read by the Pitot tube on center and the sighting rods, were first corrected for the zero readings. Then, by the tank rating curve, the quantity for each run was picked off for the corresponding tape readings. The average of the quantities obtained by the two tapes divided by the length of the run in seconds gave the quantity, $Q$, in cubic feet per second. The results of these computations are shown in Table 3, in which the pressures (corrected for zero reading), are also shown. These were not taken for all heads, because, when the gauge was raised, the water column was below the gauge. At other times, when a series of runs was rejected (which was done on several occasions in the field because of air in the tube), the pressure observations were not repeated with the other measurements. The writers plotted these pressure heads with respect to the Pitot-tube heads, but could find no regular relation. The irregularity of these pressure heads shows how unreliable they are as a means of measurement. Had they shown any regularity, they would have been used to subtract from the Pitot-tube head, in order to obtain the velocity heads. For this reason the tube could not be rated on the experimental pipes, and the traverse plottings (Plates XLV and XLVI) serve only to show the distribution of velocities. The rating on the 5-in. brass pipe is sufficient to show the action of the two.

*Plottings.*—The values of $H$ and $Q$ were then plotted (Plate XLVII) with the values of $H$ as abscissas and the values of $Q$ as ordinates. The average line through a series of points gives an equation of the form, $Q = m\ H^n$. Table 4 gives the values of $m$ and $n$ for the weir and jet conditions of each pipe.

The average lines were selected as follows: It was noted by inspection that the upper and lower parts of the series of points fell generally along separate straight lines with different slopes. Then, by starting at the higher end, a line was drawn which balanced up the points on either side; and, in the same way, a line was drawn for the lower part of the series. Inside the vertex of the angle formed by these two lines, the points seemed to fall along a well-defined curve. After several trials, curves were drawn which appeared to be the same for all pipes.

TABLE 3.—(*Continued*).

EXPERIMENTAL RUNS ON 6-IN. PIPE. ZERO OF PITOT TUBE = 0.144. ZERO OF RODS = 3.07.

| Number of run. | Head by Pitot tube on center, in feet. | Head by sighting rods, in feet. | Pressure head, in feet. | Quantity discharged, in cubic feet per second. | Remarks. |
|---|---|---|---|---|---|
| 1 | 0.041 | 0.050 | ..... | 0.0607 | Barely flowing over edge. |
| 2 | 0.063 | 0.080 | ..... | 0.1049 | Sheet form. |
| 3 | 0.088 | 0.120 | ..... | 0.167 | |
| 4 | 0.112 | 0.135 | ..... | 0.230 | Slight disturbance. |
| 5 | 0.132 | 0.150 | ..... | 0.287 | |
| 6 | 0.160 | 0.180 | ..... | 0.355 | |
| 7 | 0.184 | 0.210 | ..... | 0.432 | |
| 8 | 0.205 | 0.240 | ..... | 0.495 | Violent disturbance, swirls in circle, great variation of head. |
| 9 | 0.228 | 0.270 | ..... | 0.565 | |
| 10 | 0.253 | 0.290 | ..... | 0.650 | |
| 11 | 0.306 | 0.340 | ..... | 0.756 | Occasional spouts. |
| 12 | 0.330 | 0.370 | ..... | 0.832 | |
| 13 | 0.360 | 0.410 | ..... | 0.917 | |
| 14 | 0.410 | 0.450 | ..... | 1.002 | |
| 15 | 0.412 | 0.470 | ..... | 1.029 | |
| 16 | 0.446 | 0.470 | ..... | 1.030 | |
| 17 | 0.447 | 0.490 | ..... | 1.048 | |
| 18 | 0.507 | 0.530 | ..... | 1.089 | |
| 19 | 0.537 | 0.590 | ..... | 1.077 | |
| 20 | 0.556 | 0.580 | ..... | 1.093 | |
| 21 | 0.590 | 0.630 | ..... | 1.127 | |
| 22 | 0.600 | 0.630 | ..... | 1.139 | Column jumps as much |
| 23 | 0.671 | 0.710 | ..... | 1.203 | as 0.1 ft. Would seem |
| 24 | 0.715 | 0.770 | ..... | 1.255 | to indicate a critical |
| 25 | 0.760 | 0.830 | ..... | 1.293 | velocity. |
| 26 | 0.840 | 0.900 | ..... | 1.364 | Not so much spreading |
| 27 | 0.931 | 1.000 | ..... | 1.452 | noticed as in 9- and 12- |
| 28 | 1.015 | 1.070 | ..... | 1.518 | inch pipes. |
| 29 | 1.105 | 1.150 | ..... | 1.576 | |
| 30 | 1.216 | 1.290 | ..... | 1.675 | |
| 31 | 1.301 | 1.430 | ..... | 1.736 | Head fluctuating considerably. |
| 32 | 1.385 | 1.550 | ..... | 1.811 | |
| 33 | 1.508 | 1.680 | ..... | 1.920 | |
| 34 | 1.595 | 1.740 | ..... | 1.949 | Gauge raised. |
| 35 | 1.760 | 1.870 | ..... | 2.032 | |
| 36 | 2.030 | 2.100 | ..... | 2.201 | |
| 37 | 2.337 | 2.304 | ..... | 2.309 | |
| 38 | 2.501 | 2.590 | ..... | 2.420 | |
| 39 | 2.756 | 2.880 | ..... | 2.558 | |
| 40 | 3.098 | 3.180 | ..... | 2.713 | |
| 41 | 3.462 | 3.550 | ..... | 2.784 | |
| 42 | 3.908 | 4.000 | ..... | 3.085 | |
| 43 | 4.357 | 4.480 | ..... | 3.223 | |
| 44 | 4.557 | 5.080 | ..... | 3.437 | |
| 45 | 5.746 | 5.800 | ..... | 3.704 | |
| The following series (Pitot Tube on center, and Pressure readings) taken to show how pressure acts. | | | | | |
| ..... | 0.034 | ..... | 0.027 | ..... | |
| ..... | 0.066 | ..... | 0.056 | ..... | |
| ..... | 0.097 | ..... | 0.076 | ..... | |
| ..... | 0.119 | ..... | 0.092 | ..... | |
| ..... | 0.142 | ..... | 0.084 | ..... | |
| ..... | 0.173 | ..... | 0.102 | ..... | |
| ..... | 0.201 | ..... | 0.100 | ..... | |
| ..... | 0.225 | ..... | 0.121 | ..... | |
| ..... | 0.256 | ..... | 0.125 | ..... | |
| ..... | 0.288 | ..... | 0.102 | ..... | |
| ..... | 0.365 | ..... | 0.141 | ..... | |
| ..... | 0.402 | ..... | 0.141 | ..... | |
| ..... | 0.457 | ..... | 0.141 | ..... | |

## TABLE 3.—Observed Quantities.

### Experimental Runs on 2-in. Pipe. Zero of Pitot Tube = 0.188. Zero of Rods = 3.14.

| Number of run. | Head by Pitot tube on center, in feet. | Head by sighting rods, in feet. | Pressure head, in feet. | Quantity discharged, in cubic feet per second. | Remarks. |
|---|---|---|---|---|---|
| 1 | 0.024 | 0.020 | 0.022 | 0.0079 | Used 5-cu. ft. tank and weighing scales for measurement of quantities in first five runs. |
| 2 | 0.040 | 0.043 | 0.032 | 0.0163 | |
| 3 | 0.066 | 0.060 | 0.034 | 0.0279 | |
| 4 | 0.088 | 0.080 | 0.032 | 0.0362 | |
| 5 | 0.115 | 0.115 | 0.026 | 0.0456 | Sheet form. |
| 6 | 0.140 | 0.140 | 0.022 | 0.0538 | Slightly disturbed. |
| 7 | 0.166 | 0.160 | 0.020 | 0.0603 | |
| 8 | 0.198 | 0.195 | 0.020 | 0.0661 | Rough surface, with oscillations of water column. |
| 9 | 0.225 | 0.230 | 0.018 | 0.0731 | |
| 10 | 0.243 | 0.245 | 0.019 | 0.0781 | |
| 11 | 0.276 | 0.280 | 0.019 | 0.0828 | |
| 12 | 0.309 | 0.315 | 0.021 | 0.0869 | |
| 13 | 0.346 | 0.355 | 0.022 | 0.0927 | |
| 14 | 0.384 | 0.395 | 0.022 | 0.0988 | |
| 15 | 0.426 | 0.438 | 0.023 | 0.104 | |
| 16 | 0.453 | 0.455 | 0.023 | 0.109 | |
| 17 | 0.512 | 0.510 | 0.024 | 0.115 | |
| 18 | 0.558 | 0.550 | 0.028 | 0.124 | |
| 19 | 0.597 | 0.610 | 0.029 | 0.129 | |
| 20 | 0.655 | 0.660 | 0.031 | 0.136 | |
| 21 | 0.760 | 0.770 | 0.033 | 0.145 | |
| 22 | 0.816 | 0.815 | 0.033 | 0.148 | |
| 23 | 0.919 | 0.895 | 0.037 | 0.158 | |
| 24 | 0.979 | 0.975 | 0.042 | 0.164 | |
| 25 | 1.114 | 1.095 | 0.048 | 0.175 | |
| 26 | 1.234 | 1.205 | 0.054 | 0.185 | |
| 27 | 1.333 | 1.345 | 0.056 | 0.192 | |
| 28 | 1.477 | 1.460 | 0.057 | 0.202 | |
| 29 | 1.749 | 1.695 | ..... | 0.223 | Gauge raised 1 ft. |
| 30 | 2.140 | 2.085 | ..... | 0.251 | |
| 31 | 2.660 | 2.585 | ..... | 0.281 | Fountain jet condition apparent to the eye. |
| 32 | 3.245 | 3.110 | ..... | 0.317 | |
| 33 | 4.270 | 4.135 | ..... | 0.379 | |
| 34 | 5.335 | 5.135 | ..... | 0.419 | |
| 35 | 6.927 | 6.760 | ..... | 0.470 | |
| ..... | ..... | ..... | ..... | ..... | |

### Experimental Runs on 4-in. Pipe. Zero of Pitot Tube = 0.231. Zero of Rods = 3.17.

| Number of run. | Head by Pitot tube on center, in feet. | Head by sighting rods, in feet. | Pressure head, in feet. | Quantity discharged, in cubic feet per second. | Remarks. |
|---|---|---|---|---|---|
| 1 | 0.044 | ..... | 0.040 | 0.035 | Bulb form of discharge. |
| 2 | 0.068 | ..... | 0.058 | 0.067 | Sheet form. |
| 3 | 0.070 | 0.080 | 0.058 | 0.067 | |
| 4 | 0.093 | 0.105 | 0.068 | 0.100 | |
| 5 | 0.130 | 0.130 | 0.075 | 0.151 | |
| 6 | 0.145 | 0.150 | 0.072 | 0.174 | |
| 7 | 0.176 | 0.180 | 0.071 | 0.209 | Water column unsteady. |
| 8 | 0.195 | 0.205 | 0.066 | 0.234 | |
| 9 | 0.228 | 0.235 | 0.060 | 0.270 | |
| 10 | 0.274 | 0.270 | 0.055 | 0.310 | |
| 11 | 0.291 | 0.300 | 0.052 | 0.323 | |
| 12 | 0.312 | 0.320 | 0.052 | 0.342 | |
| 13 | 0.367 | 0.375 | 0.044 | 0.375 | |
| 14 | 0.407 | 0.415 | 0.043 | 0.407 | |
| 15 | 0.419 | 0.425 | 0.060 | 0.453 | Assuming fountain jet form. |
| 16 | 0.491 | 0.520 | 0.051 | 0.488 | |
| 17 | 0.563 | 0.590 | 0.051 | 0.523 | |
| 18 | 0.597 | 0.620 | 0.049 | 0.533 | Jet form established. |
| 19 | 0.681 | 0.680 | 0.047 | 0.555 | |
| 20 | 0.728 | 0.755 | 0.047 | 0.584 | |
| 21 | 0.813 | 0.825 | 0.047 | 0.619 | |
| 22 | 0.888 | 0.905 | 0.050 | 0.644 | |
| 23 | 1.061 | 1.080 | 0.153 | 0.712 | |
| 24 | 1.138 | 1.155 | 0.155 | 0.728 | Unsteady at about 1.3. |
| 25 | 1.285 | 1.295 | 0.057 | 0.783 | |
| 26 | 1.465 | 1.500 | 0.058 | 0.830 | Gauge raised. |
| 27 | 1.648 | 1.700 | ..... | 0.872 | Great fluctuation noted on very slight motion of gate. |
| 28 | 1.888 | 1.930 | ..... | 0.936 | |
| 29 | 2.218 | 2.230 | ..... | 1.008 | |
| 30 | 2.658 | 2.630 | ..... | 1.101 | |
| 31 | 3.021 | 2.905 | ..... | 1.103 | |
| 32 | 3.482 | 3.330 | ..... | 1.178 | |
| 33 | 4.072 | 3.780 | ..... | 1.276 | |
| 34 | 4.824 | 4.530 | ..... | 1.393 | |
| 35 | 5.681 | 5.355 | ..... | 1.540 | |
| 36 | 6.845 | 6.230 | ..... | 1.655 | |

TABLE 3.—(*Continued*).

EXPERIMENTAL RUNS ON 12-IN. PIPE. ZERO OF PITOT TUBE = 0.069. ZERO OF RODS = 3.04.

| Number of run. | Head by Pitot tube on center, in feet. | Head by sighting rods, in feet. | Pressure head, in feet. | Quantity discharged in cubic feet per second. | Remarks. |
|---|---|---|---|---|---|
| 1.. | 0.036 | ..... | ..... | 0.139 | At 1 ft. a whirling motion observed. At times, when near one edge, the water would shoot across. |
| 2.. | 0.046 | 0.055 | ..... | 0.197 | |
| 3.. | 0.060 | ..... | ..... | 0.250 | |
| 4.. | 0.081 | 0.087 | 0.123 | 0.396 | |
| 5.. | 0.095 | ..... | ..... | 0.499 | |
| 6.. | 0.129 | ..... | ..... | 0.787 | Sheet form. |
| 7.. | 0.180 | 0.180 | 0.205 | 1.127 | Slightly rough. |
| 8.. | 0.213 | ..... | ..... | 1.192 | Between 0.2 and 0.3 the flow would not settle. |
| 9.. | 0.245 | ..... | ..... | 1.477 | |
| 10.. | 0.284 | ..... | ..... | 1.760 | Below 0.235 trial by Pitot tube indicated that velocity at center was less than at edge; above this the center velocity was higher; very unsteady; appears to be a critical velocity. |
| 11.. | 0.317 | 0.290 | 0.227 | 2.051 | |
| 12.. | 0.336 | ..... | ..... | 2.602 | |
| 13.. | 0.376 | 0.380 | 0.235 | 2.673 | |
| 14.. | 0.386 | ..... | ..... | 2.804 | |
| 15.. | 0.431 | ..... | ..... | 3.070 | |
| 16.. | 0.500 | ..... | ..... | 3.487 | |
| 17.. | 0.552 | ..... | ..... | 3.922 | Getting unsteady. |
| 18.. | 0.627 | ..... | ..... | 4.309 | |
| 19.. | 0.705 | ..... | ..... | 4.868 | Bubbling begins. |
| 20.. | 0.770 | ..... | ..... | 5.213 | |
| 21.. | 0.832 | ..... | ..... | 5.552 | |

| Number of run. | Head by Pitot tube on center, in feet. | Head by sighting rods, in feet. | Pressure head, in feet. | Quantity discharged, in cubic feet per second. | Remarks. |
|---|---|---|---|---|---|
| 22.. | 0.928 | ..... | ..... | 5.960 | |
| 23.. | 1.030 | ..... | ..... | 6.367 | |
| 24.. | 1.130 | ..... | ..... | 6.759 | |
| 25.. | 1.232 | ..... | ..... | 7.128 | |
| 26.. | 1.378 | 1.340 | 0.107 | 7.698 | |
| 27.. | 1.481 | 1.650 | 0.111 | 8.073 | |
| 28.. | 1.560 | 1.760 | 0.101 | 8.358 | |
| 29.. | 1.729 | 1.890 | 0.089 | 8.754 | |
| 30.. | 1.953 | 2.150 | ..... | 9.551 | Gauge raised. |
| 31.. | 2.131 | 2.360 | ..... | 9.866 | |
| 32.. | 2.441 | 2.790 | ..... | 10.709 | |
| The following series was run to show the action of the pressure head. | | | | | |
| .... | 0.521 | 0.510 | 0.226 | | |
| .... | 0.631 | 0.610 | 0.206 | | |
| .... | 0.774 | 0.780 | 0.176 | | |
| .... | 0.876 | 0.890 | 0.153 | | |
| .... | 0.975 | 1.030 | 0.139 | | |
| .... | 1.099 | 1.180 | 0.116 | | |
| .... | 1.219 | 1.260 | 0.106 | | |

TABLE 3.—(*Continued*).

EXPERIMENTAL RUNS ON 9-IN. PIPE. ZERO OF PITOT TUBE = 0.052.

NO RODS OR PRESSURES TAKEN ON THIS PIPE. PRESSURE GAUGE AT 11.4 LB. (STAND-PIPE).

| Number of run. | Head by Pitot tube on center, in feet. | Head by sighting rods, in feet. | Pressure head, in feet. | Quantity discharged, in cubic feet per second. | Remarks. | Number of run. | Head by Pitot tube on center, in feet. | Head by sighting rods, in feet. | Pressure head, in feet. | Quantity discharged, in cubic feet per second. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1..... | 0.049 | ..... | ..... | 0.104 | Sheet discharge. | 19..... | 0.535 | ..... | ..... | 2.206 | |
| 2..... | 0.052 | ..... | ..... | 0.125 | Smooth discharge. | 20..... | 0.626 | ..... | ..... | 2.542 | |
| 3..... | 0.068 | ..... | ..... | 0.178 | Slightly rough. | 21..... | 0.656 | ..... | ..... | 2.508 | |
| 4..... | 0.087 | ..... | ..... | 0.274 | | 22..... | 0.734 | ..... | ..... | 2.779 | |
| 5..... | 0·102 | ..... | ..... | 0.334 | | 23..... | 0.799 | ..... | ..... | 2.926 | |
| 6..... | 0.147 | ..... | ..... | 0.470 | Rough. | 24..... | 0.851 | ..... | ..... | 3.070 | |
| 7..... | 0.148 | ..... | ..... | 0.717 | | 25..... | 0.897 | ..... | ..... | 3.155 | |
| 8..... | 0.188 | ..... | ..... | 0.771 | | 26..... | 0.942 | ..... | ..... | 3.246 | |
| 9..... | 0.222 | ..... | ..... | 0.832 | | 27..... | 1.141 | ..... | ..... | 3.596 | |
| 10..... | 0.223 | ..... | ..... | 0.858 | | 28..... | 1.357 | ..... | ..... | 3.987 | |
| 11..... | 0.269 | ..... | ..... | 1.130 | | 29..... | 1.532 | ..... | ..... | 4.246 | |
| 12..... | 0.278 | ..... | ..... | 1.094 | Velocity at edge greater | 30..... | 1.623 | ..... | ..... | 4.395 | |
| 13..... | 0.307 | ..... | ..... | 1.274 | than at center on one | 31..... | 1.749 | ..... | ..... | 4.543 | |
| 14..... | 0.331 | ..... | ..... | 1.362 | side of pipe. | 32..... | 1.947 | ..... | ..... | 4.853 | |
| 15..... | 0.358 | ..... | ..... | 1.536 | | 33..... | 2.172 | ..... | ..... | 5.113 | |
| 16..... | 0.391 | ..... | ..... | 1.658 | | 34..... | 2.353 | ..... | ..... | 5.358 | |
| 17..... | 0.443 | ..... | ..... | 1.833 | | 35..... | 2.564 | ..... | ..... | 5.593 | |
| 18..... | 0.493 | ..... | ..... | 2.052 | | 36..... | 2.768 | ..... | ..... | 5.841 | |

TABLE 4.—VALUES OF $m$ AND $n$ IN THE FORMULA, $Q = m H^n$.

For heads read with Pitot tube on center.

| Diameter of pipe, in inches. | Weir. | | Jet. | |
|---|---|---|---|---|
| | $m$ | $n$ | $m$ | $n$ |
| 2.08 | 1.00 | 1.29 | 0.168 | 0.54 |
| 4.09 | 2.08 | 1.28 | 0.660 | 0.496 |
| 6.197 | 3.85 | 1.29 | 1.495 | 0.52 |
| 9.172 | 6.45 | 1.31 | 3.380 | 0.548 |
| 12.586 | 9.40 | 1.27 | 6.500 | 0.54 |
| Averages ..... | ..... | 1.29 | ..... | 0.53 |

For heads read with sighting rods.

| | | | | |
|---|---|---|---|---|
| 2.08 | 1.20 | 1.352 | 0.168 | 0.55 |
| 4.00 | 2.34 | 1.351 | 0.680 | 0.50 |
| 6.197 | 3.40 | 1.337 | 1.470 | 0.53 |
| 12.586 | 10.00 | 1.341 | 6.130 | 0.56 |
| Averages ..... | ..... | 1.345 | ..... | 0.53 |

As was expected, the transition from the weir to the jet condition does not take place suddenly, but very gradually, as shown by the curved lines. This result agrees with the appearance of the actual flow, where, when the head is steadily increased, it takes considerable time to pass from the weir condition to the actual jet.

The only case which is an exception, is in the 6-in. pipe. In the plotting of this pipe, there is seen an apparently sudden change from the weir to the jet. There is a sudden bend where an increase in head does not give a corresponding increase in the quantity. It is hardly reasonable to suppose that this same condition would hold for all pipes of the same diameter, yet an explanation is difficult. When the writers noted it on the plottings they made several runs on either side and at the bend, but the result was the same as before, so that experimental error could not be held responsible. The only explanation which the writers can offer for the phenomenon is this: The inside of the pipe was machine-worked somewhat more than the other pipes, and, instead of coming gradually in to the former diameter, there was a slightly rounded angle. The diameter near the top was 0.1 in. larger than that 6 in. down. Thus, when the flow became a jet the column may have shot past the wall,

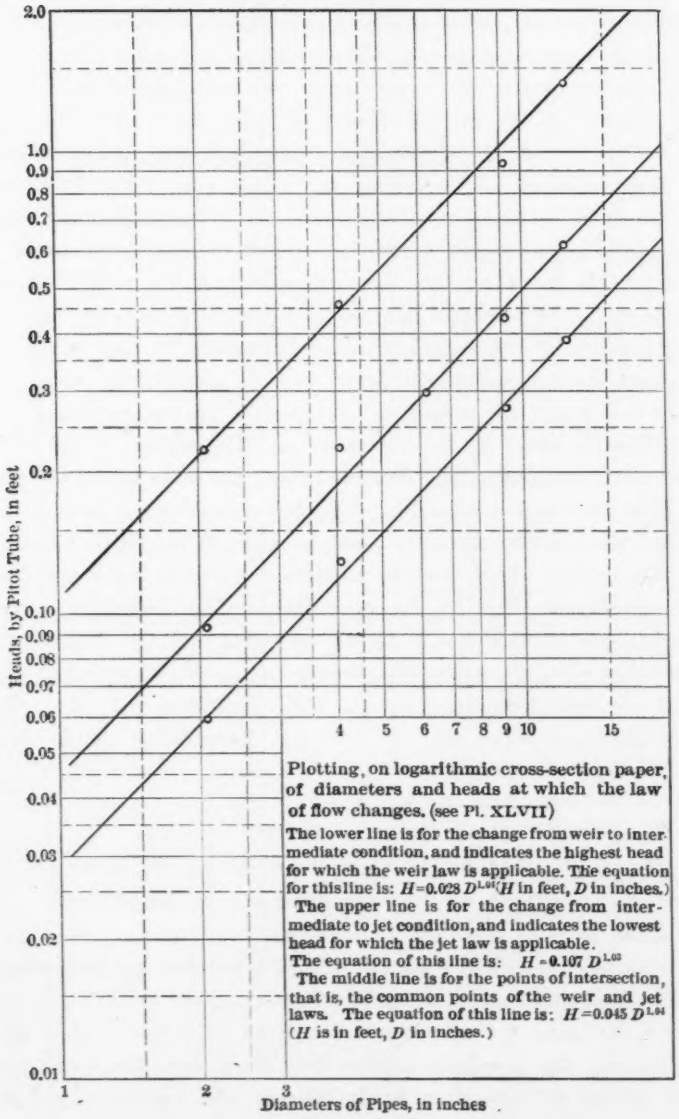

2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
Heads, by Pitot Tube, in feet
1
2
3
4
5
6
7
8
9
10
15
Diameters of Pipes, in inches
Plotting, on logarithmic cross-section paper, of diameters and heads at which the law of flow changes. (see Pl. XLVII)
The lower line is for the change from weir to intermediate condition, and indicates the highest head for which the weir law is applicable. The equation for this line is: $H=0.028\ D^{1.91}$ ($H$ in feet, $D$ in inches.)
The upper line is for the change from intermediate to jet condition, and indicates the lowest head for which the jet law is applicable.
The equation of this line is: $H=0.107\ D^{1.63}$
The middle line is for the points of intersection, that is, the common points of the weir and jet laws. The equation of this line is: $H=0.045\ D^{1.84}$ ($H$ is in feet, $D$ in inches.)

FIG. 5.

unsupported, as it does outside the pipe, so that the real diameter was the smaller one farther down. If this be so, the quantity, in cubic feet per second, should be increased. In other words, the run would actually represent that from a pipe of smaller diameter.

The jet of the 4-in. pipe shows two well-defined lines, which may have been due to the cause mentioned above. The lines representing the average of these two lines was the one finally adopted.

The plottings of quantities and heads read by sighting rods (Plate XLVII) represent similar conditions, except that the values of $m$ and $n$ are higher for the weir, and, in most cases, lower for the jet. If the Pitot tube is a true indicator, the rods were read too low for the low head and too high for the high head. The sudden jumping of the water creates an impression on the eye that the average head is somewhat higher than is actually the case. For very low heads the reflection of light on the water surface has considerable effect on the rod readings. The writers would advise the use of the hook-gauge or other means for these low heads when a Pitot tube is not available. The latter enables one to make accurate readings for these low heads, as there is very little vibration.

The points where the intermediate conditions begin and leave off are plotted (Fig. 5), for each diameter, on logarithmic cross-section paper, with the heads as ordinates and the diameters as abscissas; also, the points of intersection for the jet and weir lines were plotted for each pipe. The equations of the lines through these points can be used for determining the heads at which the intermediate conditions begin and end, for any size of pipe. The equations are:

$H = 0.028\ D^{1.04}$, for the end of the weir condition;

$H = 0.107\ D^{1.03}$, for the beginning of the jet condition;

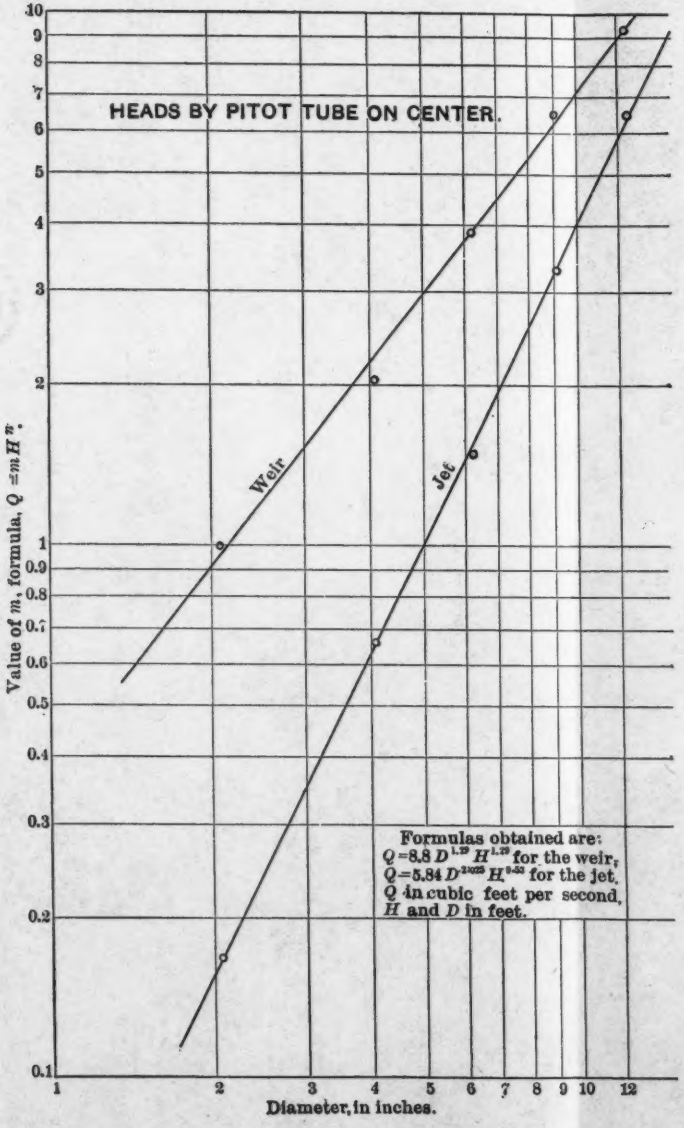
$H = 0.045\ D^{1.04}$, for the intersection of weir and jet lines.

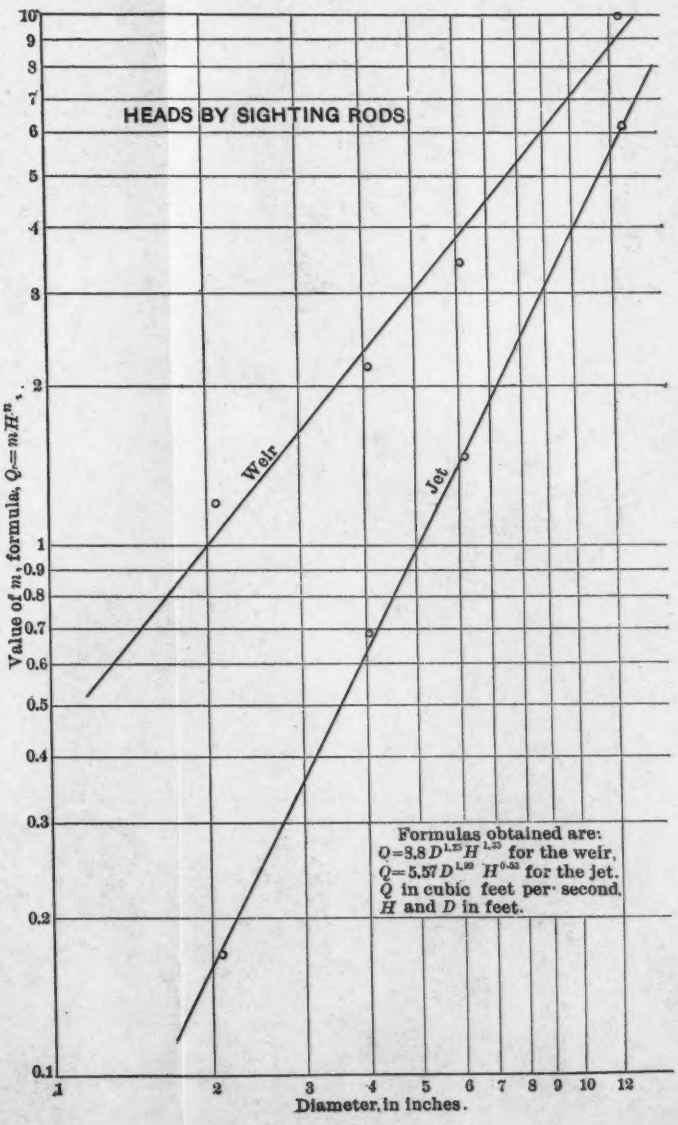
Here, $H$ is in feet, and $D$ in inches.

The fact that these lines are so nearly parallel and have almost unity slope shows that the period of intermediate condition is relatively the same for all pipes. The flows from the smaller pipes go through the transition quicker than those from the larger ones. The actual differences in heads between the beginning and end vary almost directly as the diameter.

*Final Plottings.*—The values of $m$, in the formula, $Q = m\ H^n$,

**GENERAL PLOTTING** On logarithmic cross-section paper, to determine the relation between the diameter of fountain pipe and the values of $m$ in the formula, $Q=mH^n$. The values of $m$ are those obtained from plottings of experimental data on the several pipes (see Plate XLVII).



from Table 4, were then plotted for each diameter (Plate XLVIII) on logarithmic cross-section paper for the Pitot tube and sighting rods. The values of $m$ were plotted as ordinates and the values of $D$ as abscissas. Lines through these points gave equations of the form, $m = x\ D^k$, which, substituted in $Q = m\ H^n$, gave as the final form, $Q = x\ D^k\ H^n$, in which $n$ is the average value taken from Table 4.

It was not attempted to fit any formula to the intermediate condition. Tables, which are of more practical value, were made out.

*Adjustment of Formulas.*—Using the general equation, $Q = x\ D^k\ H^n$, the heads as observed in the individual experiments were substituted, together with the corresponding diameters. This computed quantity was compared with the observed quantity, and coefficients, $\frac{Q \text{ (by formula)}}{Q \text{ (observed)}}$, were obtained. The averages of these coefficients for the weir and jet conditions of each pipe were then computed. From these average coefficients it was possible to adjust the formula so as to give an equation with the least mean error. All the points were considered except where there was clinging discharge, caused by a vacuum beneath the sheet of water. This clinging discharge generally gives a greater discharge for the same head.

The formulas finally adopted are:

For heads read with Pitot tube,

$$Q = 8.8\ D^{1.29}\ H^{1.29}, \text{ for weir flow} \quad (1)$$

$$Q = 5.84\ D^{2.025}\ H^{0.53}, \text{ for the jet flow} \quad (2)$$

For heads read with sighting rods,

$$Q = 8.8\ D^{1.25}\ H^{1.35}, \text{ for weir flow} \quad (3)$$

$$Q = 5.57\ D^{1.99}\ H^{0.53}, \text{ for the jet flow} \quad (4)$$

$Q$ is in cubic feet per second; $H$ and $D$ are in feet.

A graphical representation of the differences between the individual experiments and the general formulas is given in Figs. 6, 7 and 8. The maximum variations indicated in this plotting and in Table 5 do not represent the probable error to be expected in using the general formula. The average departures for each pipe are given in Table 5.

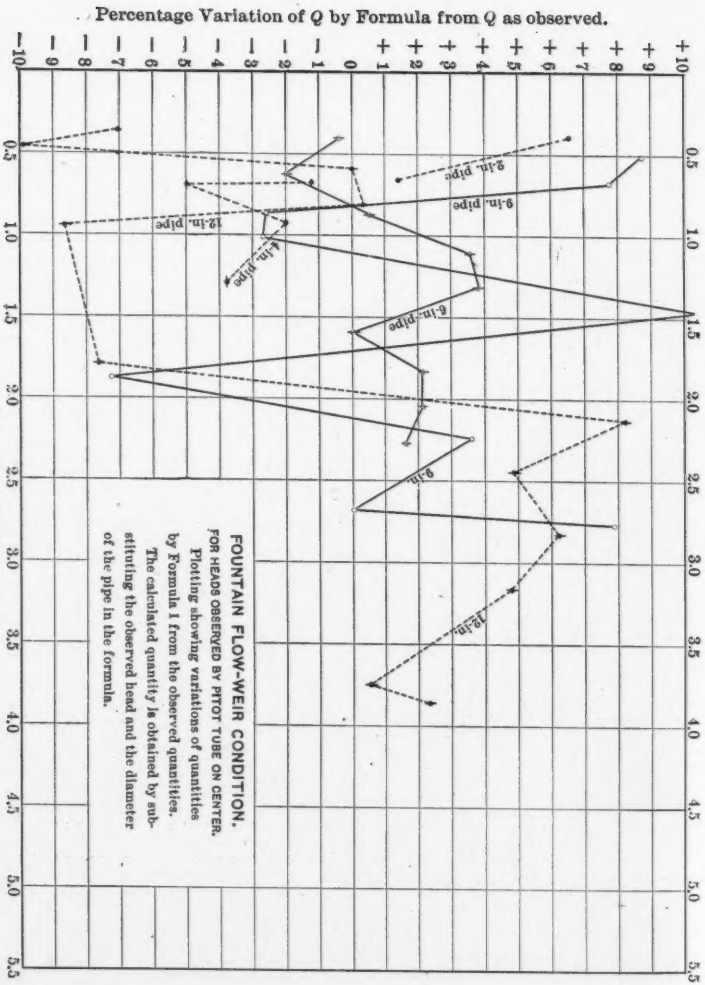

Percentage Variation of Q by Formula from Q as observed.
+10
+9
+8
+7
+6
+5
+4
+3
+2
+1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
2-in. pipe
9-in. pipe
6-in. pipe
4-in. pipe
12-in. pipe
FOUNTAIN FLOW-WEIR CONDITION.
FOR HEADS OBSERVED BY PITOT TUBE ON CENTER.
Plotting showing variations of quantities by Formula 1 from the observed quantities.
The calculated quantity is obtained by substituting the observed head and the diameter of the pipe in the formula.
Observed Heads, in feet.

FIG. 6.

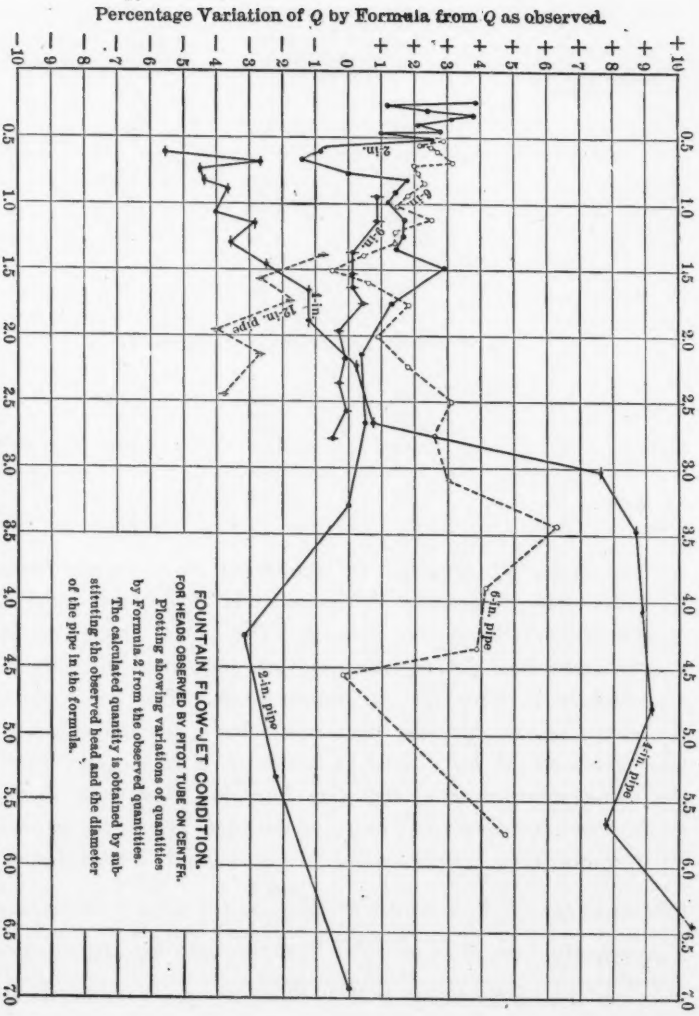

Percentage Variation of Q by Formula from Q as observed.
+10
+9
+8
+7
+6
+5
+4
+3
+2
+1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
Observed Heads, in feet.
FOUNTAIN FLOW-JET CONDITION.
FOR HEADS OBSERVED BY PITOT TUBE ON CENTRE.
Plotting showing variations of quantities by Formula 2 from the observed quantities.
The calculated quantity is obtained by substituting the observed head and the diameter of the pipe in the formula.
6-in. pipe
4-in. pipe
2-in. pipe
12-in. pipe
4-in.
3-in.
2-in.

FIG. 7.

TABLE 5.—Comparison of Results, by General Formula, with Experimental Results.

For heads read with the Pitot tube on center.

| Diameter of pipe, in inches. | Average Values of $\frac{Q \text{ (Computed)}}{Q \text{ (Observed)}}$ | | Maximum Departure of Formula from Individual Experiment. | |
|---|---|---|---|---|
| | Weir. | Jet. | Weir. | Jet. |
| 2.08 | 0.961 | 1.010 | −6.6% | −3.9% |
| 4.09 | 1.031 | 1.008 | +5.0 | −9.5 |
| 6.197 | 0.986 | 1.023 | −3.9 | −4.7 |
| 9.172 | 1.029 | 1.001 | +8.8 | −0.9 |
| 12.586 | 0.995 | 0.975 | −9.9 | +4.0 |
| Means | 1.000 | 1.008 | | |

For heads read with sighting rods.

| | | | | |
|---|---|---|---|---|
| 2.08 | 0.915 | 1.020 | − 9.3% | −5.8% |
| 4.09 | 1.046 | 0.999 | +11.8 | −5.1 |
| 6.197 | 1.071 | 1.027 | +16.8 | −4.6 |
| 12.586 | 0.900 | 0.972 | +18.0 | +6.3 |
| Means | 0.983 | 1.004 | | |

*Comparison of Results.*—In comparing the formulas obtained with the table prepared by Professor Todd (mentioned previously) considerable variation was noticed. The table, which was based on the theoretical jet formula, is very inaccurate for low heads and slightly in error for the higher heads. The lower the head for any pipe, the greater the error. In a particular case, the table gives results for a head of 0.5 in. on a 12-in. pipe, 900% of the value obtained from the weir formula. The error decreases as the head increases; but even on the high heads the theoretical jet formula gives results which are too high. The theoretical formula is $Q = F\,V$, in which $F = \frac{\pi\,d^2}{4}$ = the area of the pipe, and $V$ = velocity, from $V = \sqrt{2\,g\,h}$. These values substituted, give $Q = \frac{\pi\,d^2}{4}\sqrt{g\,h}$, or $Q = 6.30\,d^2\,H^{0.5}$, while the jet formula, obtained from these experiments, is $Q = 5.84\,D^{2.025}\,H^{0.53}$.

Messrs. Elliot and Porter (mentioned previously) obtained for the weir condition, $Q = 2.11\,H^{1.327}$, for a pipe 4.174 in. in diameter. This

Observed Heads, in feet.

FIG. 8.

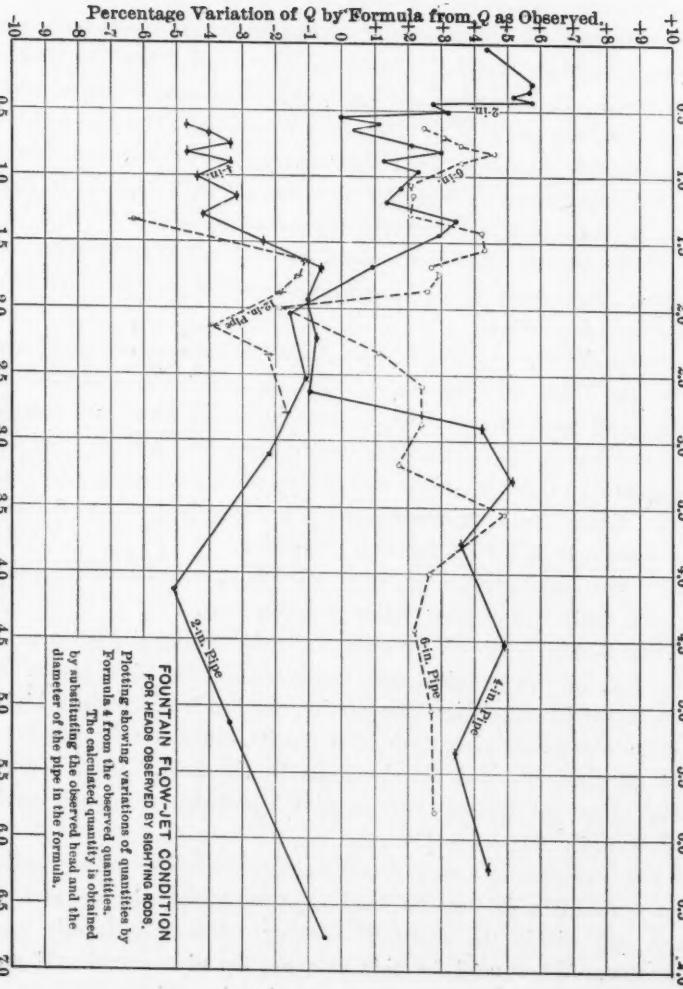

Percentage Variation of Q by Formula from Q as Observed.
+10
+9
+8
+7
+6
+5
+4
+3
+2
+1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
Observed Heads, in feet.
2-in.
6-in.
1-in.
12-in. Pipe
6-in. Pipe
4-in. Pipe
2-ins. Pipe
FOUNTAIN FLOW-JET CONDITION
FOR HEADS OBSERVED BY SIGHTING RODS.
Plotting showing variations of quantities by Formula 4 from the observed quantities.
The calculated quantity is obtained by substituting the observed head and the diameter of the pipe in the formula.

FIG. 5.

diameter, substituted in the general weir formula ($Q = 8.8\ D^{1.29}\ H^{1.29}$), gives $Q = 2.25\ H^{1.29}$. This gives a fair check on the writers' general formula.

*Diagram and Table for Practical Use of Results.*—Plate XLIX is a diagram for obtaining the quantities, in cubic feet per second, for heads from 0.02 in. to 10 ft., and for pipes from 1 to 24 in. in diameter. It is made on logarithmic cross-section paper, and is based on the general jet and weir formulas. The lines for the intermediate condition are drawn exactly like the curves obtained in the experimental plottings, and the points at which it begins and ends are obtained from the equations given.

Table 6 gives numerical values taken from this diagram. The zigzag lines separate the intermediate-condition values from the weir and jet values.

Plate XLIX and Table 6 are based on measurements of heads with the Pitot tube on center. For sighting rods, a similar diagram and table can be readily made by using Formulas 3 and 4.

*Conclusion.*—In presenting this paper, the writers feel that considerable light is being thrown on a hitherto unexplored subject. While the jet formulas are well defined, there is still room for experimentation in the weir condition.

It has been pointed out that the hitherto existing knowledge is very limited, and often leads to inaccuracy.

The heads obtained by sighting rods, while giving large errors for low heads, give very good results for high heads. As compared with the Pitot tube results, the heads are slightly higher.

The Pitot tube gives very good results, especially for low heads, and can also be used to advantage in the field. It is a device which does not require very special knowledge for good results, and is easily constructed.

*The Fountain Jet as a Measuring Device.*—The writers believe that a fountain jet can be used as a measuring device, and will come well within the limits of accuracy of most hydraulic measurements. When used for this purpose, the diameter should preferably be of such size as to form a jet, in which case very accurate results may be obtained.

In general, measuring apparatus must be adapted to the expected conditions. Thus, if a nozzle were made too large, and if

# DISCHARGE DIAGRAM FOR FOUNTAIN FLOW FROM VERTICAL PIPES.

BASED ON THE FORMULAS:

$Q = 8.8\ D^{1.39}\ H^{1.39}$ ------- For the Weir,

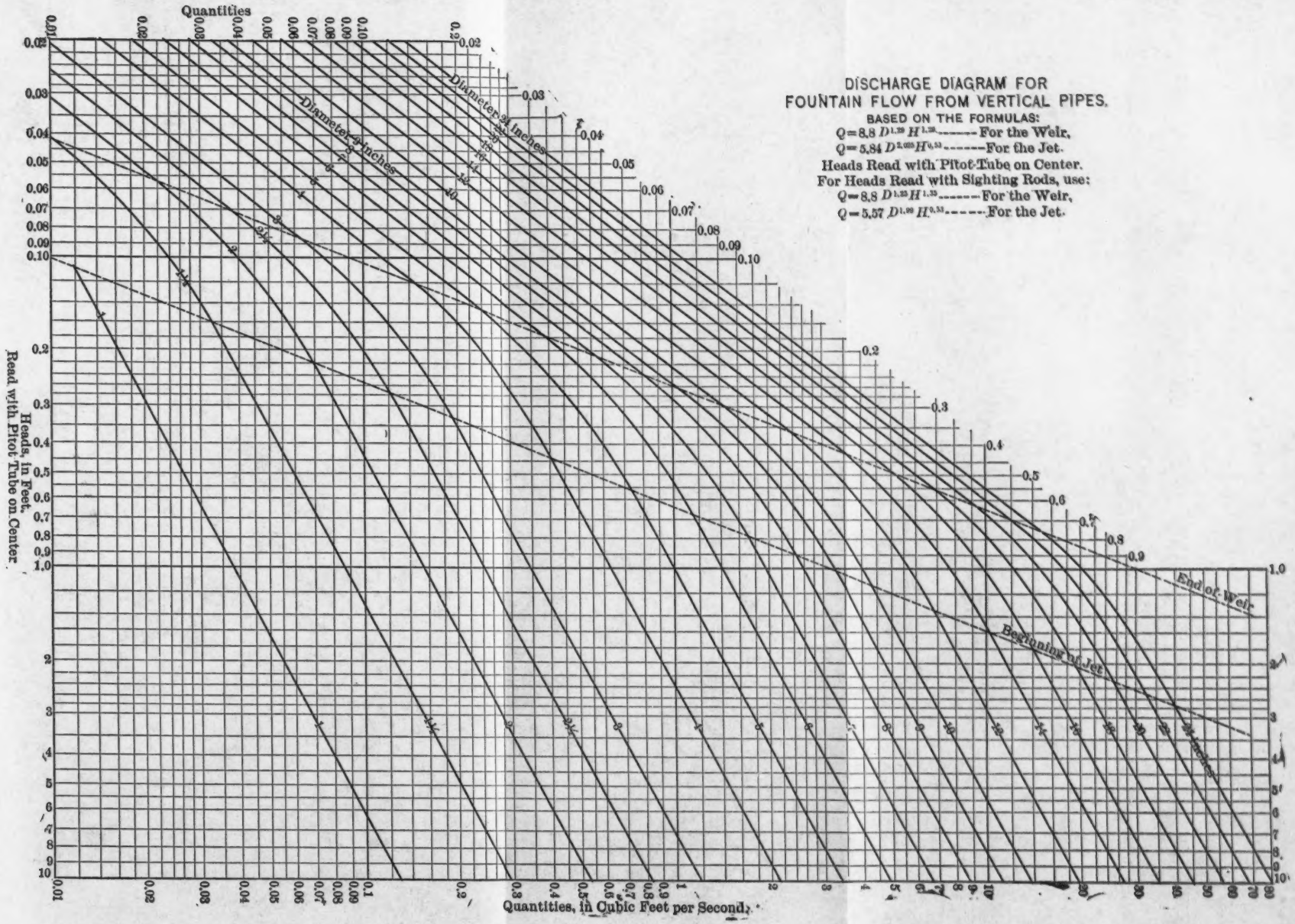
$Q = 5.84\ D^{2.025}\ H^{0.53}$ ------- For the Jet.

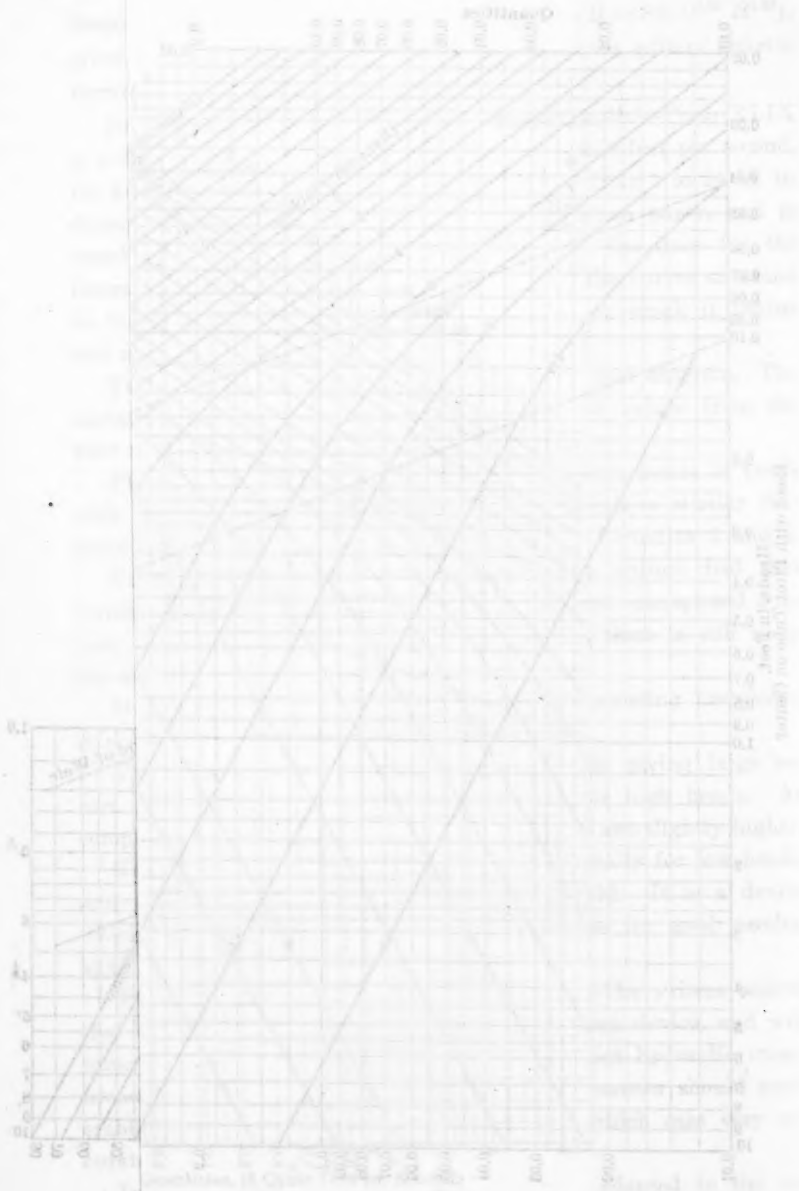
Heads Read with Pitot-Tube on Center.

For Heads Read with Sighting Rods, use:

$Q = 8.8\ D^{1.39}\ H^{1.39}$ ------- For the Weir,

$Q = 5.57\ D^{1.99}\ H^{0.53}$ ------- For the Jet.





## TABLE 6.—Discharge in Cubic Feet per Second for Fountain Flow from Vertical Pipes.

Heads from 0.02 to 10 ft.

Head Observed by Pitot Tube on Center.

From Formulas 1 and 2 and Intermediate Condition.

Weir condition above single dotted line.
Intermediate condition between the two dotted lines.
Jet condition below dotted double line.

| Head, in feet. | Diameter of Pipe, in Inches. | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 0.020 | ..... | ..... | ..... | ..... | 0.0095 | 0.0142 | 0.0179 | 0.0226 | 0.0278 | 0.0330 | 0.0381 | 0.0443 | 0.0552 | 0.0688 | 0.0802 | 0.0920 | 0.1080 | 0.1240 | 0.1340 | |
| 0.025 | ..... | ..... | ..... | 0.0096 | 0.0125 | 0.0189 | 0.0236 | 0.0301 | 0.0371 | 0.0440 | 0.0501 | 0.0588 | 0.0737 | 0.0913 | 0.1070 | 0.1210 | 0.1430 | 0.1640 | 0.1780 | |
| 0.030 | ..... | ..... | 0.0093 | 0.0125 | 0.0158 | 0.0240 | 0.0296 | 0.0382 | 0.0470 | 0.0550 | 0.0630 | 0.0735 | 0.0920 | 0.1140 | 0.1340 | 0.1550 | 0.1790 | 0.2080 | 0.2230 | |
| 0.035 | ..... | ..... | 0.0112 | 0.0153 | 0.0194 | 0.0293 | 0.0362 | 0.0466 | 0.0573 | 0.0674 | 0.0775 | 0.0905 | 0.1120 | 0.1390 | 0.1640 | 0.1890 | 0.2180 | 0.2540 | 0.2720 | |
| 0.040 | ..... | ..... | 0.0136 | 0.0181 | 0.0230 | 0.0348 | 0.0432 | 0.0555 | 0.0680 | 0.0800 | 0.0919 | 0.1070 | 0.1330 | 0.1660 | 0.1940 | 0.2230 | 0.2580 | 0.3010 | 0.3240 | |
| 0.045 | ..... | 0.0108 | 0.0158 | 0.0212 | 0.0269 | 0.0406 | 0.0501 | 0.0644 | 0.0790 | 0.0932 | 0.1070 | 0.1250 | 0.1550 | 0.1920 | 0.2240 | 0.2620 | 0.3010 | 0.3510 | 0.3780 | |
| 0.050 | ..... | 0.0122 | 0.0182 | 0.0242 | 0.0308 | 0.0465 | 0.0574 | 0.0741 | 0.0905 | 0.1060 | 0.1220 | 0.1420 | 0.1770 | 0.2200 | 0.2590 | 0.2980 | 0.3430 | 0.4020 | 0.4310 | |
| 0.055 | ..... | 0.0136 | 0.0205 | 0.0275 | 0.0349 | 0.0526 | 0.0650 | 0.0836 | 0.1030 | 0.1210 | 0.1380 | 0.1620 | 0.2010 | 0.2500 | 0.2940 | 0.338 | 0.391 | 0.457 | 0.491 | |
| 0.060 | ..... | 0.0149 | 0.0229 | 0.0307 | 0.0390 | 0.0590 | 0.0732 | 0.0935 | 0.1150 | 0.136 | 0.156 | 0.182 | 0.227 | 0.280 | 0.330 | 0.380 | 0.467 | 0.507 | 0.549 | |
| 0.065 | ..... | 0.0162 | 0.0251 | 0.0340 | 0.0433 | 0.0650 | 0.0800 | 0.1040 | 0.1278 | 0.151 | 0.172 | 0.201 | 0.250 | 0.310 | 0.364 | 0.422 | 0.484 | 0.563 | 0.610 | |
| 0.070 | ..... | 0.0174 | 0.0274 | 0.0375 | 0.0475 | 0.0720 | 0.0893 | 0.1141 | 0.1401 | 0.166 | 0.189 | 0.221 | 0.276 | 0.340 | 0.402 | 0.464 | 0.535 | 0.620 | 0.669 | |
| 0.075 | ..... | 0.0186 | 0.0295 | 0.0408 | 0.0520 | 0.0785 | 0.0980 | 0.1250 | 0.1518 | 0.181 | 0.203 | 0.243 | 0.303 | 0.375 | 0.440 | 0.504 | 0.583 | 0.680 | 0.717 | |
| 0.080 | 0.0097 | 0.0198 | 0.0317 | 0.0438 | 0.0567 | 0.0855 | 0.1070 | 0.1360 | 0.1665 | 0.197 | 0.226 | 0.265 | 0.330 | 0.406 | 0.480 | 0.550 | 0.631 | 0.735 | 0.802 | |
| 0.085 | 0.0102 | 0.0209 | 0.0337 | 0.0472 | 0.0608 | 0.0925 | 0.1150 | 0.1470 | 0.1800 | 0.216 | 0.244 | 0.287 | 0.357 | 0.440 | 0.520 | 0.595 | 0.688 | 0.796 | 0.870 | |
| 0.090 | 0.0105 | 0.0219 | 0.0356 | 0.0504 | 0.0651 | 0.0995 | 0.1230 | 0.1580 | 0.1940 | 0.230 | 0.262 | 0.310 | 0.384 | 0.473 | 0.559 | 0.642 | 0.741 | 0.854 | 0.940 | |
| 0.095 | 0.0108 | 0.0229 | 0.0376 | 0.0534 | 0.0698 | 0.1067 | 0.1330 | 0.1700 | 0.2080 | 0.245 | 0.281 | 0.330 | 0.412 | 0.506 | 0.600 | 0.684 | 0.794 | 0.920 | 1.008 | |

TABLE 6.—(*Continued*).

| Head, in feet. | Diameter of Pipe, in Inches. | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 0.650 | 0.0303 | 0.0683 | 0.1238 | 0.1939 | 0.2801 | 0.5000 | 0.7850 | 1.138 | 1.547 | 2.00 | 2.468 | 3.06 | 4.22 | 5.50 | 6.86 | 8.26 | 9.70 | 11.00 | 12.20 |
| 0.700 | 0.0316 | 0.0711 | 0.1287 | 0.2015 | 0.2916 | 0.5195 | 0.8170 | 1.180 | 1.615 | 2.095 | 2.605 | 3.22 | 4.49 | 5.87 | 7.34 | 8.91 | 10.53 | 12.10 | 13.40 |
| 0.750 | 0.0328 | 0.0738 | 0.1333 | 0.2090 | 0.3025 | 0.5390 | 0.8460 | 1.227 | 1.680 | 2.183 | 2.738 | 3.38 | 4.73 | 6.25 | 7.80 | 9.50 | 11.40 | 13.11 | 14.80 |
| 0.800 | 0.0338 | 0.0762 | 0.1380 | 0.2161 | 0.3130 | 0.5575 | 0.8765 | 1.268 | 1.740 | 2.270 | 2.850 | 3.53 | 4.97 | 6.58 | 8.23 | 10.10 | 12.13 | 14.02 | 15.95 |
| 0.850 | 0.0349 | 0.0788 | 0.1425 | 0.2230 | 0.3239 | 0.5750 | 0.9050 | 1.310 | 1.800 | 2.352 | 2.96 | 3.67 | 5.19 | 6.90 | 8.65 | 10.68 | 12.88 | 14.86 | 17.07 |
| 0.900 | 0.0360 | 0.0812 | 0.1467 | 0.2300 | 0.3330 | 0.5925 | 0.9350 | 1.351 | 1.855 | 2.427 | 3.065 | 3.80 | 5.38 | 7.19 | 9.03 | 11.22 | 13.60 | 15.70 | 18.16 |
| 0.950 | 0.0370 | 0.0837 | 0.1512 | 0.2365 | 0.3425 | 0.6110 | 0.9600 | 1.390 | 1.907 | 2.500 | 3.165 | 3.92 | 5.56 | 7.45 | 9.39 | 11.75 | 14.27 | 16.53 | 19.20 |
| 1.00 | 0.0381 | 0.0860 | 0.1550 | 0.2433 | 0.3515 | 0.6270 | 0.9860 | 1.429 | 1.960 | 2.568 | 3.270 | 4.03 | 5.73 | 7.71 | 9.71 | 12.27 | 14.99 | 17.40 | 20.20 |
| 1.1 | 0.0400 | 0.0908 | 0.1634 | 0.2559 | 0.3705 | 0.6600 | 1.040 | 1.502 | 2.061 | 2.705 | 3.430 | 4.250 | 6.080 | 8.210 | 10.380 | 13.220 | 16.130 | 18.93 | 22.07 |
| 1.2 | 0.0419 | 0.0955 | 0.1710 | 0.2680 | 0.3880 | 0.6900 | 1.087 | 1.575 | 2.160 | 2.832 | 3.600 | 4.45 | 6.39 | 8.66 | 10.95 | 14.08 | 17.20 | 20.30 | 23.78 |
| 1.3 | 0.0438 | 0.0989 | 0.1785 | 0.2795 | 0.4050 | 0.7205 | 1.135 | 1.642 | 2.252 | 2.955 | 3.760 | 4.64 | 6.69 | 9.08 | 11.48 | 14.86 | 18.20 | 21.60 | 25.35 |
| 1.4 | 0.0455 | 0.1027 | 0.1859 | 0.2910 | 0.4210 | 0.7500 | 1.180 | 1.706 | 2.343 | 3.075 | 3.905 | 4.825 | 6.97 | 9.49 | 12.00 | 15.58 | 19.12 | 22.85 | 26.80 |
| 1.5 | 0.0472 | 0.1065 | 0.1925 | 0.3015 | 0.4365 | 0.7780 | 1.225 | 1.773 | 2.430 | 3.180 | 4.055 | 5.00 | 7.22 | 9.89 | 12.50 | 16.25 | 20.00 | 23.90 | 28.08 |
| 1.6 | 0.0489 | 0.1102 | 0.1995 | 0.3125 | 0.4520 | 0.8050 | 1.267 | 1.835 | 2.515 | 3.300 | 4.195 | 5.18 | 7.48 | 10.27 | 12.99 | 16.88 | 20.80 | 24.92 | 29.30 |
| 1.7 | 0.0504 | 0.1140 | 0.2060 | 0.3220 | 0.4670 | 0.8305 | 1.306 | 1.897 | 2.600 | 3.408 | 4.330 | 5.35 | 7.71 | 10.62 | 13.45 | 17.46 | 21.55 | 25.90 | 30.50 |
| 1.8 | 0.0520 | 0.1173 | 0.2120 | 0.3320 | 0.4810 | 0.8560 | 1.350 | 1.955 | 2.678 | 3.510 | 4.465 | 5.51 | 7.96 | 10.95 | 13.90 | 18.00 | 22.36 | 26.83 | 31.60 |
| 1.9 | 0.0535 | 0.1208 | 0.2181 | 0.3420 | 0.4950 | 0.8810 | 1.388 | 2.010 | 2.755 | 3.610 | 4.590 | 5.67 | 8.19 | 11.26 | 14.33 | 18.58 | 23.00 | 27.70 | 32.70 |
| 2.0 | 0.0550 | 0.1241 | 0.2243 | 0.3515 | 0.5080 | 0.9060 | 1.426 | 2.063 | 2.832 | 3.710 | 4.720 | 5.82 | 8.41 | 11.59 | 14.70 | 19.15 | 23.60 | 28.53 | 33.75 |
| 2.2 | 0.0578 | 0.1306 | 0.2360 | 0.3690 | 0.5340 | 0.9530 | 1.500 | 2.170 | 2.978 | 3.905 | 4.970 | 6.13 | 8.85 | 12.19 | 15.47 | 20.20 | 24.96 | 30.10 | 35.60 |

TABLE 6.—(*Continued*).

| Head, in feet. | Diameter of Pipe, in Inches. | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1¼ | 2 | 2½ | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 0.100 | 0.0112 | 0.0238 | 0.0392 | 0.0564 | 0.0740 | 0.1140 | 0.1410 | 0.1805 | 0.2220 | 0.262 | 0.300 | 0.352 | 0.439 | 0.539 | 0.638 | 0.731 | 0.849 | 0.980 | 1.08 |
| 0.110 | 0.0118 | 0.0255 | 0.0427 | 0.0623 | 0.0823 | 0.1290 | 0.1510 | 0.2050 | 0.2510 | 0.298 | 0.341 | 0.400 | 0.500 | 0.611 | 0.721 | 0.882 | 0.967 | 1.11 | 1.23 |
| 0.120 | 0.0124 | 0.0270 | 0.0458 | 0.0677 | 0.0905 | 0.1440 | 0.1800 | 0.2290 | 0.2810 | 0.332 | 0.381 | 0.447 | 0.558 | 0.682 | 0.805 | 0.937 | 1.10 | 1.24 | 1.37 |
| 0.130 | 0.0129 | 0.0284 | 0.0489 | 0.0723 | 0.0981 | 0.1555 | 0.2000 | 0.2550 | 0.3120 | 0.372 | 0.422 | 0.495 | 0.619 | 0.760 | 0.903 | 1.06 | 1.22 | 1.38 | 1.52 |
| 0.140 | 0.0134 | 0.0299 | 0.0517 | 0.0769 | 0.1055 | 0.1715 | 0.2210 | 0.2800 | 0.3430 | 0.406 | 0.463 | 0.543 | 0.681 | 0.839 | 1.00 | 1.16 | 1.34 | 1.51 | 1.68 |
| 0.150 | 0.0139 | 0.0312 | 0.0544 | 0.0810 | 0.1123 | 0.1841 | 0.2410 | 0.3070 | 0.3750 | 0.442 | 0.508 | 0.599 | 0.742 | 0.920 | 1.08 | 1.28 | 1.47 | 1.66 | 1.84 |
| 0.160 | 0.0144 | 0.0324 | 0.0569 | 0.0853 | 0.1185 | 0.1965 | 0.2610 | 0.3330 | 0.4080 | 0.483 | 0.552 | 0.648 | 0.811 | 1.00 | 1.18 | 1.38 | 1.59 | 1.80 | 2.00 |
| 0.170 | 0.0148 | 0.0336 | 0.0592 | 0.0892 | 0.1245 | 0.2090 | 0.2810 | 0.3600 | 0.4420 | 0.521 | 0.600 | 0.701 | 0.881 | 1.07 | 1.28 | 1.49 | 1.72 | 1.94 | 2.16 |
| 0.180 | 0.0153 | 0.0346 | 0.0613 | 0.0930 | 0.1302 | 0.2208 | 0.3000 | 0.3860 | 0.4750 | 0.561 | 0.642 | 0.753 | 0.950 | 1.16 | 1.38 | 1.60 | 1.85 | 2.09 | 2.33 |
| 0.190 | 0.0158 | 0.0356 | 0.0633 | 0.0966 | 0.1359 | 0.2323 | 0.3180 | 0.4120 | 0.5100 | 0.600 | 0.683 | 0.805 | 1.02 | 1.24 | 1.48 | 1.73 | 1.99 | 2.25 | 2.49 |
| 0.200 | 0.0162 | 0.0365 | 0.0654 | 0.1000 | 0.1407 | 0.2427 | 0.3360 | 0.4380 | 0.5460 | 0.645 | 0.733 | 0.867 | 1.08 | 1.325 | 1.58 | 1.87 | 2.12 | 2.40 | 2.66 |
| 0.250 | 0.0182 | 0.0417 | 0.0746 | 0.1150 | 0.1642 | 0.2880 | 0.4150 | 0.5600 | 0.7080 | 0.857 | 0.990 | 1.17 | 1.44 | 1.78 | 2.11 | 2.49 | 2.84 | 3.20 | 3.52 |
| 0.300 | 0.0201 | 0.0454 | 0.0821 | 0.1285 | 0.1839 | 0.3250 | 0.4800 | 0.6620 | 0.8570 | 1.032 | 1.22 | 1.47 | 1.81 | 2.22 | 2.64 | 3.12 | 3.60 | 4.08 | 4.45 |
| 0.350 | 0.0218 | 0.0497 | 0.0892 | 0.1395 | 0.2021 | 0.3580 | 0.5390 | 0.7500 | 0.9900 | 1.22 | 1.43 | 1.75 | 2.22 | 2.72 | 3.23 | 3.81 | 4.40 | 4.97 | 5.45 |
| 0.400 | 0.0234 | 0.0529 | 0.0957 | 0.1495 | 0.2170 | 0.3855 | 0.5900 | 0.8320 | 1.081 | 1.362 | 1.63 | 2.02 | 2.66 | 3.24 | 3.84 | 4.50 | 5.20 | 4.90 | 6.50 |
| 0.450 | 0.0250 | 0.0562 | 0.1019 | 0.1591 | 0.2310 | 0.4105 | 0.6360 | 0.9180 | 1.190 | 1.51 | 1.816 | 2.26 | 3.01 | 3.79 | 4.49 | 5.16 | 6.09 | 5.85 | 7.58 |
| 0.500 | 0.0264 | 0.0595 | 0.1078 | 0.1683 | 0.2440 | 0.4350 | 0.6770 | 0.9750 | 1.291 | 1.646 | 1.99 | 2.47 | 3.35 | 4.24 | 5.08 | 5.98 | 6.95 | 6.82 | 8.62 |
| 0.550 | 0.0278 | 0.0626 | 0.1131 | 0.1772 | 0.2566 | 0.4570 | 0.7170 | 1.030 | 1.385 | 1.773 | 2.155 | 2.68 | 3.66 | 4.69 | 5.75 | 6.80 | 7.90 | 8.84 | 9.86 |
| 0.600 | 0.0291 | 0.0655 | 0.1185 | 0.1855 | 0.2695 | 0.4785 | 0.7520 | 1.085 | 1.468 | 1.89 | 2.313 | 2.87 | 3.90 | 5.11 | 6.30 | 7.57 | 8.80 | 9.90 | 11.00 |

TABLE 6.—(*Continued*).

| Head, in feet. | Diameter of Pipe, in Inches. | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 6.2 | 0.1000 | 0.2235 | 0.4080 | 0.6400 | 0.9260 | 1.655 | 2.598 | 3.770 | 5.160 | 6.76 | 8.60 | 10.62 | 15.32 | 21.10 | 26.81 | 35.00 | 43.40 | 52.40 | 62.60 |
| 6.4 | 0.1020 | 0.2303 | 0.4160 | 0.6510 | 0.9410 | 1.681 | 2.641 | 3.830 | 5.250 | 6.88 | 8.75 | 10.80 | 15.60 | 21.50 | 27.29 | 35.60 | 44.15 | 53.30 | 63.65 |
| 6.6 | 0.1035 | 0.2340 | 0.4225 | 0.6620 | 0.9580 | 1.710 | 2.682 | 3.900 | 5.335 | 7.00 | 8.90 | 11.00 | 15.82 | 21.81 | 27.73 | 36.20 | 44.80 | 54.10 | 64.70 |
| 6.8 | 0.1052 | 0.2379 | 0.4295 | 0.6720 | 0.9620 | 1.739 | 2.730 | 3.960 | 5.415 | 7.10 | 9.03 | 11.18 | 16.10 | 22.20 | 28.19 | 36.75 | 45.60 | 55.05 | 65.70 |
| 7.0 | 0.1066 | 0.2413 | 0.4355 | 0.6830 | 0.9870 | 1.761 | 2.768 | 4.020 | 5.500 | 7.205 | 9.18 | 11.32 | 16.34 | 22.52 | 28.60 | 37.30 | 46.25 | 55.90 | 66.70 |
| 7.2 | 0.1083 | 0.2455 | 0.4420 | 0.6930 | 1.005 | 1.790 | 2.810 | 4.080 | 5.590 | 7.315 | 9.32 | 11.50 | 16.60 | 22.86 | 29.08 | 37.90 | 47.00 | 56.80 | 67.80 |
| 7.4 | 0.1100 | 0.2486 | 0.4490 | 0.7020 | 1.020 | 1.815 | 2.853 | 4.400 | 5.670 | 7.42 | 9.46 | 11.64 | 16.82 | 23.20 | 29.46 | 38.45 | 47.70 | 57.55 | 68.80 |
| 7.6 | 0.1115 | 0.2523 | 0.4555 | 0.7130 | 1.032 | 1.841 | 2.890 | 4.200 | 5.750 | 7.53 | 9.58 | 11.85 | 17.06 | 23.53 | 29.90 | 39.00 | 48.35 | 58.35 | 69.90 |
| 7.8 | 0.1130 | 0.2560 | 0.4615 | 0.7230 | 1.046 | 1.868 | 2.935 | 4.260 | 5.820 | 7.63 | 9.72 | 12.00 | 17.32 | 23.85 | 30.35 | 39.55 | 49.00 | 59.15 | 70.70 |
| 8.0 | 0.1147 | 0.2590 | 0.4675 | 0.7320 | 1.060 | 1.892 | 2.970 | 4.315 | 5.905 | 7.73 | 9.84 | 12.18 | 17.55 | 24.19 | 30.70 | 40.05 | 49.70 | 60.00 | 71.60 |
| 8.2 | 0.1161 | 0.2627 | 0.4740 | 0.7430 | 1.074 | 1.920 | 3.015 | 4.375 | 5.990 | 7.84 | 9.99 | 12.33 | 17.78 | 24.50 | 31.15 | 40.60 | 50.35 | 60.80 | 72.50 |
| 8.4 | 0.1176 | 0.2660 | 0.4800 | 0.7520 | 1.086 | 1.941 | 3.050 | 4.430 | 6.060 | 7.95 | 10.10 | 12.49 | 18.00 | 24.80 | 31.60 | 41.10 | 51.00 | 61.55 | 73.50 |
| 8.6 | 0.1191 | 0.2695 | 0.4865 | 0.7620 | 1.100 | 1.966 | 3.085 | 4.485 | 6.140 | 8.04 | 10.23 | 12.65 | 18.22 | 25.12 | 31.95 | 41.65 | 51.60 | 62.30 | 74.40 |
| 8.8 | 0.1205 | 0.2730 | 0.4920 | 0.7710 | 1.113 | 1.993 | 3.130 | 4.540 | 6.210 | 8.14 | 10.36 | 12.80 | 18.45 | 25.42 | 32.30 | 42.15 | 52.30 | 63.10 | 75.30 |
| 9.0 | 0.1220 | 0.2760 | 0.4980 | 0.7800 | 1.126 | 2.015 | 3.160 | 4.590 | 6.290 | 8.23 | 10.47 | 12.95 | 18.66 | 25.73 | 32.70 | 42.65 | 52.90 | 63.90 | 76.20 |
| 9.2 | 0.1234 | 0.2792 | 0.5040 | 0.7900 | 1.140 | 2.040 | 3.200 | 4.650 | 6.360 | 8.33 | 10.60 | 13.11 | 18.90 | 26.00 | 33.05 | 43.20 | 53.50 | 64.60 | 77.10 |
| 9.4 | 0.1248 | 0.2825 | 0.5100 | 0.7990 | 1.152 | 2.062 | 3.240 | 4.700 | 6.430 | 8.43 | 10.73 | 13.25 | 19.10 | 26.35 | 33.50 | 43.70 | 54.20 | 65.30 | 78.00 |
| 9.6 | 0.1263 | 0.2860 | 0.5150 | 0.8070 | 1.166 | 2.085 | 3.275 | 4.760 | 6.510 | 8.52 | 10.85 | 13.41 | 19.32 | 26.62 | 33.80 | 44.15 | 54.80 | 66.05 | 78.90 |
| 9.8 | 0.1275 | 0.2886 | 0.5220 | 0.8180 | 1.179 | 2.107 | 3.315 | 4.810 | 6.590 | 8.62 | 10.98 | 13.56 | 19.55 | 26.93 | 34.20 | 44.65 | 55.30 | 66.90 | 79.90 |
| 10.0 | 0.1290 | 0.2920 | 0.5270 | 0.8250 | 1.190 | 2.130 | 3.350 | 4.860 | 6.640 | 8.70 | 11.07 | 13.69 | 19.79 | 27.20 | 34.60 | 45.10 | 56.00 | 67.60 | 80.55 |

TABLE 6.—(*Continued*).

| Head, in feet. | Diameter of Pipe, in Inches. | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 2.4 | 0.0605 | 0.1367 | 0.2469 | 0.3870 | 0.5600 | 1.0000 | 1.572 | 2.277 | 3.115 | 4.085 | 5.20 | 6.41 | 9.26 | 12.75 | 16.20 | 21.15 | 26.22 | 31.60 | 37.50 |
| 2.6 | 0.0632 | 0.1426 | 0.2576 | 0.4040 | 0.5830 | 1.0410 | 1.640 | 2.373 | 3.260 | 4.265 | 5.42 | 6.70 | 9.67 | 13.30 | 16.92 | 22.08 | 27.39 | 33.05 | 39.30 |
| 2.8 | 0.0657 | 0.1485 | 0.2680 | 0.4200 | 0.6080 | 1.082 | 1.701 | 2.470 | 3.380 | 4.44 | 5.64 | 6.97 | 10.02 | 13.84 | 17.60 | 23.00 | 28.45 | 34.40 | 41.00 |
| 3.0 | 0.0681 | 0.1540 | 0.2779 | 0.4350 | 0.6300 | 1.160 | 1.765 | 2.562 | 3.510 | 4.60 | 5.86 | 7.22 | 10.42 | 14.36 | 18.25 | 23.80 | 29.50 | 35.65 | 42.55 |
| 3.2 | 0.0704 | 0.1595 | 0.2876 | 0.4500 | 0.6520 | 1.163 | 1.830 | 2.651 | 3.630 | 4.765 | 6.05 | 7.48 | 10.80 | 14 85 | 18.86 | 24.61 | 30.60 | 36.90 | 44.00 |
| 3.4 | 0.0727 | 0.1645 | 0.2970 | 0.4655 | 0.6730 | 1.200 | 1.886 | 2.740 | 3.755 | 4.915 | 6.25 | 7.71 | 11.14 | 15.33 | 19.50 | 25.45 | 31.55 | 37.10 | 45.45 |
| 3.6 | 0.0750 | 0.1699 | 0.3065 | 0.4800 | 0.6950 | 1.240 | 1.947 | 2.825 | 3.870 | 5.07 | 6.45 | 7.95 | 11.48 | 15.81 | 20.08 | 26.21 | 32.50 | 39.25 | 46.85 |
| 3.8 | 0.0772 | 0.1746 | 0.3155 | 0.4945 | 0.7150 | 1.275 | 2.000 | 2.903 | 3.980 | 5.21 | 6.63 | 8.20 | 11.81 | 16.27 | 20.66 | 26.99 | 33.50 | 40.45 | 48.20 |
| 4.0 | 0.0794 | 0.1795 | 0.3240 | 0.5070 | 0.7340 | 1.325 | 2.060 | 2.985 | 4.085 | 5.36 | 6.81 | 8.41 | 12.15 | 16.72 | 21.25 | 27.70 | 34.35 | 41.55 | 49.60 |
| 4.2 | 0.0814 | 0.1841 | 0.3325 | 0.5210 | 0.7530 | 1.342 | 2.110 | 3.070 | 4.200 | 5.50 | 7.00 | 8.63 | 12.46 | 17.19 | 21.82 | 28.46 | 35.30 | 42.60 | 50.90 |
| 4.4 | 0.0836 | 0.1886 | 0.3410 | 0.5330 | 0.7720 | 1.380 | 2.165 | 3.140 | 4.300 | 5.63 | 7.18 | 8.86 | 12.80 | 17.60 | 22.39 | 29.20 | 36.15 | 43.70 | 52.10 |
| 4.6 | 0.0854 | 0.1932 | 0.3490 | 0.5470 | 0.7900 | 1.425 | 2.215 | 3.215 | 4.400 | 5.77 | 7.34 | 9.06 | 13.08 | 18.01 | 22.91 | 29.86 | 37.00 | 44.75 | 53.40 |
| 4.8 | 0.0873 | 0.1976 | 0.3570 | 0.5590 | 0.8080 | 1.441 | 2.270 | 3.290 | 4.505 | 5.90 | 7.51 | 9.27 | 13.40 | 18.42 | 23.42 | 30.55 | 37.85 | 45.95 | 54.60 |
| 5.0 | 0.0893 | 0.2020 | 0.3650 | 0.5710 | 0.8260 | 1.475 | 2.320 | 3.360 | 4.600 | 6.03 | 7.67 | 9.48 | 13.67 | 18.81 | 23.90 | 31.20 | 38.70 | 46.70 | 55.80 |
| 5.2 | 0.0912 | 0.2062 | 0.3720 | 0.5830 | 0.8430 | 1.505 | 2.365 | 3.430 | 4.700 | 6.17 | 7.83 | 9.69 | 13.99 | 19.22 | 24.44 | 31.90 | 39.55 | 47.75 | 57.00 |
| 5.4 | 0.0930 | 0.2103 | 0.3800 | 0.5950 | 0.8600 | 1.538 | 2.415 | 3.500 | 4.800 | 6.285 | 8.00 | 9.88 | 14.25 | 19.62 | 24.93 | 32.55 | 40.30 | 48.75 | 58.10 |
| 5.6 | 0.0949 | 0.2148 | 0.3870 | 0.6070 | 0.8780 | 1.566 | 2.463 | 3.575 | 4.890 | 6.405 | 8.15 | 10.06 | 14.52 | 20.00 | 25.42 | 33.15 | 41.10 | 49.70 | 59.30 |
| 5.8 | 0.0968 | 0.2185 | 0.3945 | 0.6190 | 0.8940 | 1.595 | 2.507 | 3.640 | 4.970 | 6.515 | 8.30 | 10.25 | 14.80 | 20.40 | 25.90 | 33.80 | 41.85 | 50.55 | 60.40 |
| 6.0 | 0.0988 | 0.2225 | 0.4015 | 0.6290 | 0.9100 | 1.625 | 2.553 | 3.705 | 5.065 | 6.64 | 8.45 | 10.43 | 15.05 | 20.55 | 26.39 | 34.40 | 42.60 | 51.50 | 61.40 |

TABLE 6.—(*Continued*).

the flow through it moved too slowly, the errors involved in using it for a measuring device might be considerable; for a certain head over a weir, there must be a proper height and length of weir for the best results; a Venturi meter must have its ratio of contraction depending on the range of velocities in the pipe line.

A fountain jet with sighting rods, or with a Pitot tube, is an exceedingly simple and cheap measuring device for the discharging end of a pipe line. Any form of Pitot tube having a coefficient of unity may be used. The form used by the writers is very easily constructed, and answers the purpose admirably. Adequate sighting rods are available almost anywhere.

*Accuracy.*—In using the formulas given, or the diagram, (Plate XLIX), or Table 6, it may be remarked that the writers' results (see Table 5 and Figs. 6, 7 and 8) indicate that the average accuracy to be expected for any particular pipe in measurements of fountain flow with the jet condition, using either sighting rods or the Pitot tube, is within 3% of the truth. For the weir condition, the average accuracy with the Pitot tube is within 4 per cent. The sighting rods give a maximum average error of 10% for the weir flow. A single measurement of fountain flow by either of these means cannot be considered reliable within twice the above stated maximum average errors.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## ENGINEERING PATENTS.

An Informal Discussion at the Annual Convention, June 27th, 1906*

SUBJECT FOR DISCUSSION.

"THE PROTECTION OF THE INTELLECTUAL PROPERTY OF CIVIL ENGINEERS."

BY MESSRS. D. A. USINA AND J. P. A. MAIGNEN.

D. A. USINA, ASSOC. AM. SOC. C. E. (by letter).—The application of the patent laws to the work of civil engineers presents certain interesting peculiarities; and, in connection with these, is to be considered the question of protecting such intellectual products of the engineer as are not reached by the law. Mr. Usina.

Civil engineers are here spoken of in the more restricted sense; not including mechanical or electrical engineers, chemists, or metallurgists, or others whose works may be multiplied many times without substantial changes; but referring more particularly to the builders of great hydraulic works, systems of water distribution and sewerage, great dams, railway systems, bridges, and buildings in steel or masonry. Works of the latter class cannot be exactly duplicated. Each dock or harbor improvement presents fresh problems. Though the details of railways, bridges, and buildings, and even certain large features of design, have become more or less standardized, yet there is not the capability of duplication regardless of conditions which exists in mechanical or electrical machines or chemical products or processes.

* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings*, in order that the views expressed may be brought before all members of the Society for further discussion.
If additional communications on this subject are received, they will appear in the *Proceedings* for September.

Mr. Usina. Each work of this sort calls for originality. A scheme for tunneling the East River might be impracticable for the Hudson River; or a scheme for tunneling the Hudson might involve expenses entirely unnecessary in other situations. A civil engineer is called upon to display originality in each new work which arises. The "skill of the profession" involves, not only fundamental knowledge, but an ability to apply it to constantly varying situations. To a much less degree is this originality required in other professions.

But this originality, this inventive quality, is not as well rewarded by our patent laws as the same degree of originality in designing new machines. The design of a new pumping engine, for example, may be multiplied a thousand times, while a new tunnel, involving a greater degree of invention, will be capable of use in but one or two locations. During seventeen years the inventor of the pump is receiving royalties based upon the value of his one improvement. The tunnel engineer, on the other hand, because his work is adapted only to one situation, receives but a single payment—the usual engineer's fee.

There are, of course, some circumstances under which civil engineers have found it advantageous to protect by patent an invention which was capable of use in only one location. For example, the intention of the Pennsylvania Railroad to build a tunnel under the Hudson River was so well advertised, and the peculiar difficulties so thoroughly discussed in the technical journals, long before the work was let, that many engineers conceived original and ingenious solutions of the difficulties; and, in order that they alone might profit by their ingenuity, secured patents for the processes proposed. Speaking from recollection, there were more than a dozen such patents issued at about the time the work was to begin. Such a patent, of course, may be highly remunerative if it proposes a plan which is clearly the best, and if it secures for the patentee the contract to build the work, or a royalty for the use of his idea; but it is not likely to be of value unless adopted on this particular work.

The civil engineer, however, ordinarily includes his inventive ability in the services for which he is retained, and receives no reward for a good design except a "well done" from the few who can appreciate the difficulties which he has surmounted. Out of this fact undoubtedly springs the skeptical attitude of many civil engineers toward patents. One of our best known bridge engineers recently said, of a patented bridge:

"Why, there's no room for a patent there! It's merely a nice application of known engineering principles to a peculiar set of circumstances."

Mr. Usina.

Yet the design of the patented bridge was certainly new, and it is not safe to say that any good engineer, given the same problem, would have evolved the same design. In fact, the range of possible solutions is so great as to make it improbable that any two engineers would have arrived at the same solution of the problem; and experience shows that they seldom do arrive at the same solution. Is it not fair, then, to give the inventor the benefit of so much as is original with him? This is all that the patent law aims to do. New principles cannot be patented, nor obvious applications of old principles; but, in exchange for his giving to the world the benefit of his original inventive ability, the law purposes to give the inventor a monopoly of his creation for a limited term.

The distinction which the law makes against devices the conception of which involves only the expected skill of the profession, is illustrated by a case which came under the writer's personal observation some years ago. An application was filed for a patent for a railway system, including express tracks and local tracks, with outside local stations and "island" express stations at which passengers could transfer from local to express trains, such as now used in the Manhattan subway. The advantages were set forth in detail, and could not be denied. Nor could any previous record of such a system be found. Yet the very liberal Examiner of the Civil Engineering Division held that a good engineer, given conditions favoring the utilization of such a design, would naturally evolve it; and the patent was properly refused.

In reference to the law, the word "purposes" is used advisedly. The work of law-makers is no more perfect than that of engineers; and the execution of the law by men introduces another fallible element. What is an "obvious" application of known principles, as distinguished from a true invention involving more than the expected skill of the profession? There are thirty-eight examiners in the Patent Office, and each has his own standard of what constitutes invention. By a wise provision of the law, they are expected to give applicants the benefit of any doubt, but, however the standard may be stated in words, there will be as many interpretations of it as there are examiners. The tendency of many examiners, and especially of those newly appointed, is to regard applications for patents as little better than attempts to obtain monopolies to which the applicants are not entitled, and this tendency results in putting upon applicants the often heavy burden of proving that they are entitled to a patent.

Civil engineers have been fortunate in that they have had for many years at the head of the Division of Civil Engineering an examiner with broad ideas, who has looked upon his work as not merely obstructive. But the writer has known applications, par-

Mr. Usina. tially allowed by this examiner, to be transferred to another examiner recently appointed, and to be by him rejected *in toto;* and not because of the discovery of any new grounds of rejection, but because of a narrower view and less familiarity with the art in question, and probably because of a fear of taking the responsibility of allowing a patent the validity of which was not absolutely certain. The law contemplates the allowance of a patent unless it is clearly invalid, but this examiner refuses it unless its validity is practically certain. There are appeals, of course, but they are expensive, and the attitude of the primary examiner determines in a large degree the nature of the patents issuing from his particular division of the Patent Office.

The ethical proposition has been advanced that it is the duty of the civil engineer to give to the public the benefit of his invention; that his function is to advance his art and to assist his brethren in doing the same thing; in other words, to give to all engineers freedom to use the methods and tools which his brain has created. And this is not to be denied. In only one other profession—the medical—is the same philanthropic view held.

But this view is not inconsistent with a monopoly for a limited period of time. Seventeen years, the term of a patent, is not a very long period in the progress of an art, and the ultimate advance is not retarded by such a monopoly. On the other hand, the reward which may be gathered in this limited term is a stimulus to invention, and a just compensation for the study and the often heavy expense needed to reduce a mere idea to a practical and useful embodiment. The legal theory of a patent is that it is a contract in which each party gives an equivalent. The Government gives a limited monopoly; the inventor gives to the world a complete description such as will enable others to use his invention when the monopoly expires. And patents have been held invalid for lack of such a full, clear and exact description as will put the invention at the disposal of the public. The consideration for the monopoly having been withheld by the inventor, the monopoly has also been withheld.

The large works of civil engineers are seldom duplicated in a period of seventeen years, and the rewards, in the shape of royalties, upon patents for such works, are not numerous; but that is rather a reason for granting than for denying the patent. There is very little danger of imposing on the public. The courts give to an infringer of a patent ample opportunity for showing, either by publications or by actual works, that the patentee was not the original and first inventor of the matter in question. And though the grant of a patent by the Patent Office carries with it a presumption of validity, yet this presumption may be easily over-

thrown if it is not justified in fact. The law requires that the patentee shall give a full, clear and exact disclosure of the invention, that he shall be the true inventor, and that the conception shall involve more than the expected skill of the calling. Under these circumstances, justice certainly calls for a reward proportional to the benefit conferred upon the subsequent users of the invention. Mr. Usina.

This reward is noticeably a great stimulus to invention (and the extreme liberality of our patent laws, as compared with those of foreign countries, is certainly largely responsible for the fecundity of the American inventor). There are numerous instances of the spending of years of time and thousands of dollars in reducing to practical, usable form a conception of the greatest benefit to mankind, where the inventor's only sure reward depended on a monopoly of the perfected invention.

A patent is not a hindrance to the progress of any art. It gives something additional to what was known before. It takes away nothing. The art may continue to progress along its old lines if the patentee should exercise his restrictive powers to the limit. It is especially true of civil engineering works that they may generally be built in more than one way. This is a corollary of the fact that two engineers will seldom arrive independently at the same solution of a problem involving new conditions. Therefore, a patent for a new method of building a railway tunnel under the Hudson River, for example, will not give the patentee any influence in the matter, except in so far as his plan is clearly and greatly superior to others.

Engineers are often heard to decry the common practice of state and national authorities in calling for original plans with the bids for great works, and in sometimes letting the work to one bidder to be carried out according to the plan of another. This is nothing short of piracy; the appropriation of the intellectual property of another. This abuse is more often varied by the appropriation of the best features of two or more plans. Large corporations are sometimes guilty of the same offense, but the governmental authorities are the principal sinners in this direction. It is not always possible to guard against such misappropriation by the taking of patents, but the designer is nevertheless entitled to a reward commensurate with the value of the thing given, and the American Society of Civil Engineers could well establish and maintain among its members a method of procedure which would ensure a suitable reward in case of such an appropriation of the product of the engineer's intellect. The remedy by patent reaches a limited number of such cases; the others can be reached only by concerted action among the best engineers. This proposition of concerted action is not new; but, under existing laws, there is no other

Mr. Usina. remedy for the abuse, and it would not seem to be difficult to put it into effect.

It is in line with this obviously correct view of an engineer's intellectual property that he should have the right to control its use, and, in so far as patents are adapted to this end, they are a reasonable benefit. Engineers of the highest standing have taken this view. Witness the caisson and tunneling patents of Flad, Eads, Sooysmith, and Greathead; the sewerage patents of Waring; the bridge patents of Fink, Pratt, Burr, Howe, and Whipple. Some of these last show constructions which are enormities in the light of our present knowledge; but, without the work of these men and the stimulus which the patent laws gave to them, bridge building might still be far behind its present degree of perfection.

Mr. Maignen. J. P. A. MAIGNEN, ASSOC. AM. SOC. C. E.—This question is exceedingly interesting. There are three classes of engineers: the consulting engineer, the salaried engineer and the independent engineer.

The consulting engineer, like the physician, stands on a high plane, and his reputation is his patent. He is bound to give to the profession the benefit of his discoveries. His intellectual property seems to be protected sufficiently by his reputation.

The salaried engineer, who is paid to do a certain work, may, of course, have new ideas as the result of his experience. If his invention is strictly in line with his work, he, of course, owes the invention to his employer. If it is but slightly related to his work, it is still his duty to offer the benefit of the invention to his employer on terms of mutual agreement. If the employer refuses to have anything to do with the invention, or to join in the expense for its development, the salaried engineer is free to act as he thinks best, but it is clear that it is not proper for him to take advantage of the time and facilities provided by the employer in order to further exclusively his individual interests.

The position of the independent engineer is altogether different. He spends his own time and his own money (or that of his friends) in the field of research. He is not employed as a consulting engineer at $100 per day, nor as a salaried engineer at $10 000 or $20 000 per year. He works in the hope of finding a useful improvement and of interesting somebody in his invention. Perhaps he succeeds in both. A patent is taken, and he wishes to place his invention on the market. What happens then? The consulting engineer resolutely sets himself against all proprietary inventions, and the salaried engineer dares not recommend them for fear of being accused of participation in the profits.

A short time ago the speaker received a letter from an official of the Water Department of Albany, N. Y., in which he was in-

formed that the charter of that city did not allow any proposition for patented inventions to be entertained. Is it, then, a crime to take out patents? Patentees are considered as dreamers, or extortioners by some engineers. Is this right? Mr. Maignen.

In the speaker's opinion, patents are only labels for the protection of original ideas. If the patented product were not better or cheaper than the unpatented one, who would even think of adopting the former?

At the International Engineering Congress, at St. Louis, in 1904, a late lamented member of the Society gave expression to the small esteem in which patents are held by engineers, saying, in effect: "Of course, there is nothing perfect (in sewage disposal) except patent processes!"

Another member, to whom the foregoing was related, told the speaker of a friend of his, who called on the general manager of a great railroad corporation, and said, "I have come to see you about a patent." "I have no time for patents," said the manager. The visitor retorted, "Ah! this is how you manage the affairs of the railroad; you do not want to look at anything which is less than seventeen years old. Good-by." The manager's pride was touched, the effect was produced, he called the visitor back and had plenty of time to listen to his proposition.

Among certain engineers there is a feeling which has found expression in books, that, as long as any process is patented, it should not be considered. This is wrong. Every proposition should be considered on its own merits, whether patented or not.

The independent engineer usually has not the means to exploit his inventions; he must appeal to capital. Capital cannot be enlisted unless the invention is protected by a patent, but when the money and the patent are obtained, then the real difficulty begins. All the odds are against the inventor. He is looked upon with scorn or pity. Is this as it should be? The Government takes the money of the inventor in order to protect his intellectual property for a time sufficient to enable him to recoup himself for expended resources and to make an honorable living. When the limit of time has been reached, every one benefits by the process. Where would be the great industries, such as steel, the telegraph and the telephone, if they had not been protected by patents?

Our forefathers saw the difficulty. The Franklin Institute, of Philadelphia, and La Société d'Encouragement pour l'Industrie Nationale, of Paris, have established special committees to examine and report upon new inventions, and have provided funds to reward the inventor with money premiums. In 1895 the speaker received a money prize of 500 francs, from the Société d'Encouragement, for his work in purifying water.

Mr. Maignen. Now, would it not be well for the National Government, for some State institution, or for some of the millionaires who have done so much for education, to establish such a society in the United States, to reward inventors in the beginning, before they are disheartened by the coldness and opposition of interested parties? Their requirements would be small. The independent engineer, or inventor, does not want millions; he would be very well satisfied with what is now given for a short time to consulting or salaried engineers. The inventions would then be put on the market at once, with every chance of success, on account of the unbiased report and recommendation of the scientific commission which had ascertained their value, and the whole world would benefit by them without delay.

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# PAPERS AND DISCUSSIONS.

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## ENGINEERING EDUCATION.

An Informal Discussion at the Annual Convention, June 27th, 1906.*

SUBJECTS FOR DISCUSSION.

"What is the Best Preparatory Education for the Civil Engineering Profession?"

"Is Technical Training the Best Education for Executive Work?"

BY MESSRS. GEORGE F. SWAIN, HAROLD BOUTON, GEORGE W. RAFTER, EDGAR MARBURG, GARDNER S. WILLIAMS AND OLIN H. LANDRETH.

Mr. Swain.

GEORGE F. SWAIN, M. AM. SOC. C. E. (by letter).—Most people will admit to-day that civil engineering, like other branches of engineering, belongs to the learned professions, and should require a preliminary technical training corresponding generally to that necessary for the lawyer or the physician. There is much to be said for the old apprentice system of becoming an engineer, or for the method by which a young man enters an engineer's office after an ordinary public school education, and slowly works his way along, studying as he learns, by doing, the practical details of the profession. Engineering is more—much more—common sense and "gumption" than it is science, and the school cannot make up for a lack of these qualities. Many of our best and most deservedly

* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
If additional communications on this subject are received, they will appear in the *Proceedings* for September.

Mr. Swain. eminent engineers are men who, by force of character and perseverance, have worked themselves up in this way. Yet these men would probably be the first to acknowledge the great advantage which a proper technical education would have been to them, and they would not consider for a moment bringing up their sons in the way which they followed. Yet it is probable that they fail to realize the benefits which they derived from the stern discipline of actual life, and from the necessity which they were under of making up for lack of opportunity by hard work and diligent application. The trouble with the young man, between the ages of sixteen and twenty-two, who is given the opportunity of a higher education, is that he fails to realize his opportunity, and does not take advantage of it; and, as a result, many of the graduates of technical schools and colleges have neither accurate knowledge of any one subject, nor the ability to think clearly and logically, nor the power of taking up a new subject and mastering its fundamental principles without assistance.

"I would set all the young men to work," said Socrates, "and send all the old men to school." And this, while of course impracticable, involves a deep and fundamental truth, namely, that we learn mostly by experience, rather than by precept, and that only as we approach middle life do we awaken to the advantages of thorough training and accurate knowledge. Experience is the greatest of all teachers, but is an expensive one. The great difficulty that confronts the teacher is to awaken the student to a sense of his responsibility and his opportunity, to make him patient and even anxious of correction, and to make him see that the true object of his education is to train himself to accurate thinking, to high ideals, and to a proper balance of all his faculties, so that he may make of himself the best that is possible. As Dr. Munger has said, "Education is to teach us how to live, not how to make a living."

It is undoubtedly true, however, that most young men who go to a professional school with a proper sense of the opportunity, and embrace it earnestly, will get from the course what they could not, or at all events would not, get without it. But the technical school cannot make an engineer; it can only give the opportunity for the young man to acquire a training, an independence of mind, a character, which will make him first of all a man, and show him how to live, and further, to acquire a familiarity with the fundamental principles of science, which he ought to know in order to be an intelligent engineer instead of a parrot, an imitator, a rule-of-thumb man. The degree does not and cannot make the engineer, though some schools apparently deceive themselves by thinking that it does. The school cannot even teach; it can only offer

opportunities for a man to learn, for nothing is of real value in this world but what we gain by our own efforts. The college is not a restaurant, where young men come to be filled, but a gymnasium, where opportunities are offered for the development of all the faculties, not only mental, but physical and moral. It is self-evident that a development of this kind is the proper and necessary training for the highest success in any profession, and while such development can in some instances be obtained independent of the school, yet a school which offers suitable opportunities ought to give what most men would not be apt to obtain if left to themselves. After all, we are creatures of habit, and habits acquired in early life, whether physical, mental, or moral, are apt to remain and if bad are hard to eradicate; hence the importance of acquiring proper habits of thought, as well as of action, as early as possible. Mr. Swain.

Assuming, then, as a fundamental proposition, that a technical education is the proper preparation for the civil engineering profession, and that few men have the character, the courage, and the perseverance, to be able to develop themselves unaided, the question remains, what should be the character of that education, and how far it should go. We confront once more the old question, which so many able minds have discussed. "What knowledge is of most worth?" In considering this question, with reference to engineering education, one must never forget that the aim here, as in all other education, should be first of all to make men. Engineering education must not be narrow, must not be confined to strictly professional subjects, but must be broad enough to develop the man on all sides. At the same time, we must remember one of the fundamental principles of the modern education, which is, that of two subjects which will give equally good training, the more useful one should be chosen. There is no excuse, at the present day, for teaching subjects which will be of no possible use to a man in his professional or social relations, simply because they afford good mental training, when there are many useful subjects which, if properly taught, afford just as good or even better training. The interest of the student will lie with the subject for which he can see a use, and interest is a necessary factor in education. But even the useful subjects cannot all be taught in a technical course of the usual length, or even in a college course followed by a professional course. Some selection must be made. And here it will be well to bear in mind that, as President Eliot once said, "the actual problem is not what to teach, but how to teach." We must not endeavor to teach everything which a man will need, but must make a judicious selection of subjects, and teach these thoroughly, in such a way that the student will gain the power to take up and master new subjects by himself. And here is reached one

Mr. Swain. of the fundamental and greatest defects of education at the present day. Too much attention is devoted to the question, what shall be taught, and too little, or sometimes almost none at all, to the question, how it should be taught. Much time is devoted to the arrangement of the curriculum, and then an important subject is assigned to a teacher who can neither interest the students nor make them understand it; or who, perhaps, instead of training them to think, and giving them in this way some power of doing things they have never done before, simply turns his class-room into a restaurant, and fills his pupils up with facts, the bearings of which they are unable to appreciate, and which they promptly forget. Comparatively little attention is paid to the appointment of teachers, it being assumed, apparently, that if a man understands a subject, or appears to understand it, he can teach it to others. It is not made a requisite for the teacher's post that a man shall have been trained in pedagogics, that he shall know something of the theory and history of education, or of psychology; these things are neglected, and men are often appointed to high positions as teachers who have had no training in education, who have to learn that science as they would any other, and meanwhile, at the expense of their pupils. Good teachers are extremely rare, and the faculty for teaching is a gift, perhaps to a greater extent than most faculties. With some men it is almost intuitive, and such men do not require much training. But with most men it has to be learned. Too many men teach because they could not succeed in practical business life, and, as a matter of fact, many of them cannot teach efficiently. Ask the best men in a class from any of our colleges or professional schools, and they will probably agree in telling you of important courses from which, through no fault of their own, they derived neither information, nor training, nor inspiration. It is a great pity that the results of education cannot be quantitatively expressed, and shown at the end of the year, in a balance sheet, in dollars and cents; and, further, that trustees and faculties are not dependent for their income upon the results of such a balance sheet. To pursue this line of thought would carry us too far, but the writer's advice, to the young man who wishes to study any subject whatever, is to go to the institution where there are the best teachers of that subject. Material equipment, laboratories, and so forth, are of no consequence in comparison. Mark Hopkins at one end of a log and a student at the other make a university. The teachers of engineering should study, not only engineering, but teaching, and should study the latter more than the former. One of the most encouraging educational steps in recent years in America has been the formation of the Society for the Promotion of Engineering Education. The profession of teaching is one of the most

important to the community, but it is not recognized as it ought to be, and it is not paid as it ought to be. Some universities, even, expect to obtain men competent to teach all branches of civil engineering and to occupy positions where they should be inspirers of young men to mental achievements and to high moral ideals, and all for $1 200 a year. And even the American Society of Civil Engineers does its part, the writer regrets very much to say, to keep down and render unattractive the profession of teaching, by refusing to recognize the work of a teacher in charge of a department of engineering as professional experience in charge of work. This Society has preferred to recognize, as eligible to full membership, the man who has had a few years' experience in giving lines and grades for sewers, or superintending simple practical engineering works, in preference to the man who is in charge of an engineering department of a technical school, and devotes himself to teaching and inspiring the future members and leaders of the profession. In the writer's opinion, this Society can do no better work, to raise the dignity of engineering teaching and of the engineering profession, than to remove this restriction from its Constitution. It will gain much, and lose nothing, by recognizing experience in teaching as equal to experience in practice as a requisite for membership. Mr. Swain.

The curriculum of an engineering course should be almost entirely prescribed, with few optional or elective studies. The main opportunity for election should be between different lines of study, as for instance between civil engineering, mechanical engineering, electrical engineering, etc., but the line or aim once chosen, the course should be laid out by competent teachers, and should be prescribed. The idea that students should be obliged to undertake difficult and unpleasant tasks simply because they are difficult and unpleasant is happily outgrown, but life is full of such tasks, and one of the most useful results of a proper system of training is the ability to do drudgery and to attack and surmount difficult tasks cheerfully and successfully. One of the dangers of a too literal and extreme application of the elective system is that, improperly understood, it cultivates a tendency to shirk difficulties and a disposition to avoid unpleasant tasks.

One more point is to be considered. If the desirability of breadth and utility is granted, the question is, whether they should be arrived at simultaneously or successively. It is held by many that they should be attained successively; that the public school or secondary school, which gives a boy his preparatory education, should be followed by the college, which gives him his broad general education, and this by the professional school, which gives him his technical education. This is the zone theory of education. The

Mr. Swain. difficulty with this arrangement is that during his college course the student is working less earnestly and with a less definite aim in view than if he were pursuing a professional course from the beginning. Every institution of learning should be looked upon primarily as a place where young men and women go to do hard work; and it should be impossible for anybody to remain in the institution who does not come in this spirit and conform to this requirement. Healthful and wholesome amusements, recreation and exercises should be a part of the training, but secondary to the main objects in view. A wrong attitude toward college work prevails to a great extent, not only among young men, but among their parents as well. It is unfortunately true that in most or at least in many colleges numbers of young men dawdle away their time, doing little or nothing except to cram for examinations; and that they emerge with little except a diploma and an enlarged cranium, and, perhaps, with a bad habit or two. This should be made impossible. The writer has never been connected with a college, but he knows from long experience how difficult it is to make even students in a professional school awaken to a due sense of their opportunities, and of the proper relations of things; and it must be much more difficult in a college, where a larger proportion of students are browsing around without any definite aim, and having a good time incidentally, giving no serious consideration, before graduating, to the question of their future careers. If this view is correct, it would seem to follow that the student should be urged to select as early as possible his professional course, at least within broad limits, and that during his college course, if he takes one, he should lay out his studies with distinct reference to his future professional course. It would also seem that some non-technical subjects should be carried on, even in the professional school, so that interest in such studies should not be entirely lost. Change of occupation is rest, and studies of different kinds, as for instance history and mathematics, may each prove a recreation to a mind wearied with the other. Such an arrangement as has been outlined is really a continuous professional course from the beginning, in which the proportion of professional studies increases in each year; it allows the student to work always with a definite aim in view, and at the same time the proportion of technical work in the early years is not so great as to preclude a change of course if the student comes to feel, as he advances, that some other branch of professional work than the one first selected seems to be better fitted for his capacities.

Summing up the preceding discussion, the following are the principles which the writer would lay down in answer to the question which has been propounded:

Mr. Swain.

1.—A technical education as given in our civil engineering schools is, if properly appreciated and made use of, the best preparation for the practice of the profession; and at the present day it is almost a necessity.

2.—In laying out an engineering course, the aim should be, first of all, to develop broad-minded men, who can observe correctly, reason logically, express themselves in language and on paper, men with imagination and with character, and with good physical development.

3.—Useful subjects of study, which admit and require training in thinking, should be preferred to studies which are mere accomplishments.

4.—Studies which involve discipline of the mind and observation should be preferred to those which merely give information.

5.—Subject to the above restrictions, what is taught is not as important as how it is taught. The teaching profession should be better paid and made more attractive to able men.

6.—The curriculum leading to any of the engineering professions should be almost entirely prescribed.

7.—The choice of a profession should be made as early as practicable, and a continuous course should be arranged with that profession in view, from the beginning of the higher education. A course of five years, or perhaps of six years, either in one institution or in two, seems to be desirable for a thorough preparation.

8.—The American Society of Civil Engineers should recognize the dignity of the teaching profession by making experience in teaching equal to experience in practice as a requirement for membership.

Passing now to a consideration of the question "Is Technical Training the Best Education for Executive Work?" the writer's reply would depend upon the character of the technical training, that is, upon what is taught, and more especially upon how it is taught. It is a common criticism that graduates of technical schools are narrow, and that, while suited for subordinate positions, they are not as well qualified for high administrative positions as college men. The writer believes that, taken broadly, this criticism is unsound—that is to say, he does not believe that the average college man is better fitted for administrative work, or is any broader, than the average technical graduate. Nevertheless, he believes that there is much suggestiveness in the charge, and that the technical schools may profit by considering it. The number of college graduates is very much greater than the number of technical graduates, and probably a larger proportion of the latter are from humble homes, where they have been denied social advantages, and are lacking in polish, and perhaps in good manners.

Mr. Swain. They have gone to the technical school because they knew that they would have to earn their own living, for which they were obliged to prepare themselves as quickly as possible, and they have, by inheritance as well as by force of circumstances, a tendency to take an interest only in the practical professional work, and to give little attention to acquiring breadth of interest or comprehensiveness of view. They have looked at everything from the professional standpoint, and with a magnifying glass, and they lack the mobility of mind that would enable them to take in a problem or a condition in its entire scope, or to appreciate all the various sides of a question. Such an attitude is not that of the successful administrator. The man who looks at a thing through a microscope sees more—but he also sees less—than the man who looks with the unaided eye; and the tendency in any detailed study of a scientific or technical problem is to concentrate so much attention on the details that the general relations are not perceived. The engineering student is constantly under this temptation, and unless it is counteracted by good teaching, it may soon become a habit. Unfortunately, here again many teachers fail to do what they should, being narrow themselves, or lacking in a knowledge of the large practical relations of the subjects which they teach. Engineering students constantly seem to the writer to be like men studying a book with a microscope; who can tell the details of each particular portion of the work, but who have failed to see what it was all about.

It is not apparent to the writer, however, that engineering studies are very different from other studies in a narrowing tendency. How many students of history, for instance, arrive at correct general conclusions or accurate ideas regarding the general tendencies of a period? Here, as in the study of science, there seems to be about equal opportunity for spending so much time upon detail that general relations are obscured.

A certain largeness of vision is essential for administrative work, but, in order to judge correctly as to the relative value of technical and general education as a preparation, we must, not only consider what technical education can be, and ought to be, but, instead of comparing college graduates with technical graduates, we must consider whether the same man would be better fitted by the college course or by the technical course. In doing this, the following are some of the elements to be considered:

1.—Most executive or administrative work has to do with engineering, or involves engineering as an important element. Our railroads, mines, manufacturing establishments, etc., depend upon applied science, that is, upon some branch of engineering. A knowledge of engineering, therefore, if it is accompanied by breadth of

view, largeness of conception, and the personal qualities necessary, must be of great advantage in rendering the administrative officer able to form his own opinions, and in enabling him to direct the energies of his staff in the directions most productive of efficiency, economy, and industrial development. Mr. Swain.

2.—Scientific study certainly has the great moral advantage of training men to search for truth, to keep their minds open until a result is obtained, and to be satisfied with no makeshifts or evasions. Such an attitude of mind must be consonant with the highest kind of administration, however much it may conflict with the necessities of politics, graft, or deception, which seem to be the ruling elements in some executive positions.

3.—Scientific study and the pursuit of truth for its own sake conduces to honesty, both of mind and of action, to frankness and fearlessness, and to uprightness of purpose. However narrow engineers may be, the writer believes that for these qualities just mentioned they are not excelled by the members of any other profession.

4.—Technical training, and particularly technical experience in the handling of men, is clearly of advantage in any executive position.

After a consideration of these elements, the writer—while ready to admit the fact that many men technically trained lack the breadth of view and adaptability which is essential in executive work—believes nevertheless that technical training, if the course of study is properly laid out, with a proper proportion of liberalizing studies, and pursued under teachers who direct the students always toward the larger view, is the best preparation for executive work.

HAROLD BOUTON, ASSOC. AM. SOC. C. E. (by letter).—The question in regard to the best preparatory education for the civil engineer deserves the interest and very earnest thought of every member of this Society. Mr. Bouton.

The subject is of very great importance and should be accorded more than a casual or indifferent discussion. Some radical measures should be undertaken to change the conditions which are responsible for the inability of a layman to distinguish between a qualified engineer and a fraud or as incompetent. Incompetency should be reduced to a minimum. Fraud should be eliminated.

The very question seems to infer that some preparatory education is necessary, unless the writer is mistaken in the import of the word "education" as used, and that experience alone will satisfy its definition. But, at the present time, who can practice as a civil engineer? Anybody; anyone, of any age, character or manner of education. With himself as the sole judge of his own qualifications, he has only to claim this distinction in order to set up its practice.

Mr. Bouton. As a matter of fact, who do practice? They may be divided into four classes:

1.—Frauds;
2.—Those depending on practical experience alone;
3.—Those ambitious enough to have prepared themselves as well as circumstances, wisdom and capacity permitted;
4.—Those who have taken technical courses under the instruction and supervision of others.

The frauds have been confined to the first class. The incompetent are not confined to any. They may be found in all four.

A few results of this condition of indiscriminate freedom of practice are:

1.—Lack of respect, if not contempt, by laymen, for the accuracy, ability and responsibility of the profession at large;
2.—Loss of its dignity as a profession;
3.—No recognized code of ethics;
4.—Contempt for a technical or preparatory education by those brilliant geniuses who know by instinct or natural aptitude and without study the rules and laws of mathematics and Nature;
5.—No standard basic course, defined for those who desire preparation, but who have to undertake it without the assistance of the instructor;
6.—The graduation from technical courses of at least fifty-seven varieties of civil engineer; most of them specialists;
7.—The ease with which some degrees can be procured;
8.—Lack of protection for those who blindly undertake a technical course of which they can know nothing more than that it will graduate them as C. E., if they will comply with its requirements;
9.—Loss of time and money to ambitious students in technical courses without adequate return;
10.—Disregard for the best methods of economic engineering design, practice and construction;
11.—Disregard for the laws, circumstances, and conditions, governing the locality and project;
12.—Faith in handbooks as the gospel of engineering;
13.—Ignorant, dangerous and extravagant design;
14.—Fraudulent, illegal, unjust, indefinite, and inadequate specifications and contracts;
15.—Excessive cost to employers;

16.—Low grade of construction to prevent excessive cost to contractors; Mr. Bouton.
17.—Innumerable law-suits;
18.—Endangering of the health, safety, and interests of the public.

Some of the causes responsible for the foregoing conditions are:

1.—Entire lack of any regulation by Federal or State governments, or this Society, of who shall practice;
2.—Lack of requirement for education of any kind;
3.—Lack of minimum requirement of preparation of all who desire to practice;
4.—Lack of uniformity and practicability in technical courses, as to time required, methods and subjects of study;
5.—Lack of intelligent application of theory to practice;
6.—Incompetent instructors;
7.—Specialization of technical courses with insufficient foundation of the primary principles;
8.—The present policy of this Society, that experience is alone sufficient without any preparatory education whatsoever, for admission to all grades;
9.—And that the experience of an axeman during his seventeenth and eighteenth years is accepted as an equivalent for graduation from a recognized school of engineering for admission as Junior;
10.—Indifference of the profession at large to the deplorable conditions.

The public deserves better protection. The dignity of a responsible profession involving the most nearly exact sciences, requires it.

Is it feasible to change this state of affairs? It has proven so in law and medicine, neither of which can be made as exact as engineering. The Federal and many State governments require a test satisfying various civil service regulations of those entering the public service.

Law and medicine, in the majority of instances, deal with the safety and affairs of an individual or a few. Engineering deals mostly with those of a multitude.

Statutory law is as various as the local necessities, customs or policies of the States and Territories. Its specialties are only limited in number by the varying phases of human affairs and intercourse. This has not prevented the almost universal requirement that there shall be a minimum preparation upon which to base the

Mr. Bouton. practice of law. On the contrary, the general sentiment and tendency is for a higher standard.

In every civilized country certain essential preparation is required of those who desire to practice medicine or surgery. Public policy has necessitated a license, in order to eliminate or limit the quack. But that profession itself has done much to merit the confidence necessarily reposed in it. The annual convention of the American Medical Association, held this same year and month in Boston, advocates a higher standard than ever before, and a better supervision of professional schools.

The architects, whose profession most nearly resembles Engineering, have examined the question. At present it is said that the States of New Jersey, Illinois and California require a license for the practice of architecture.

In New York State, in 1901, agitation in this regard resulted in a meeting being called by the Architectural League of New York and a preliminary committee being appointed to find with what favor the profession at large would consider a bill drawn for presentation to the State Legislature to institute a compulsory registration of architects.

"Circulars asking for the expression of opinion for or against the proposed legislation were sent to 995 architects, and elicited 520 replies, classified as follows: In favor of legislation, 493; against legislation, 20; not in favor of draft of bill as issued, or otherwise doubtful, 7. The Buffalo, Brooklyn and Central New York chapters of the American Institute of Architects endorsed the legislation proposed."

The movement failed.

"The New York chapter of the American Institute of Architects put itself on record as opposed to any legislation (at that time). Its reasons were briefly:

"No law should be urged unless, if enacted, the result will be positive and beneficial. No law can possibly be enforced at present which will take away from any individual the right to design and construct his own building, or to have this work done by anyone whom he may select, even though he be not a registered architect. The apparent analogy with the bar and medical profession does not exist, as only members of the bar and regular physicians are allowed to practice in this State; and the registered architect will have an empty title with no powers or rights attached. No examination can deal with other than constructive knowledge and among the registered architects will certainly occur many names which one hestitates to recognize as properly entitled to be called architects. The anomaly will be presented of architects registered by the State on account of presumed constructive knowledge, while the engineers, whose special attribute is such knowledge, are not registered. Architects properly desire to be considered members of the artistic fra-

ternity, rather assimilated to painters and sculptors than to strictly professional men, as lawyers and physicians, or to craftsmen, as builders and plumbers; and this position will not be advanced by State registration. Architectural societies, and especially the American Institute of Architects, furnish the best means for conferring deserved distinction on the members of the profession; a State license will not confer such distinction."* Mr. Bouton.

How much strength there is to these objections, generally, it is no part of this discussion to argue. As to the alleged illegality, no further comment need be made than to suggest the inherent police power of a State to regulate whatever may affect the health and safety of its citizens; and of which power the building codes of different localities are examples. In addition, it may be said, of the claim somewhere made, that where engineering problems are presented or involved, it is customary to call in an engineer, leaving the artistic side to the architect. Were this done, which it is well known is not the general custom, it means calling in any engineer, with the consequent chance of competency. But, one will say, the local building code must be complied with. True, but who draws that? Any engineer or architect, or perhaps political favorite, who has sometime built a cellar wall.

The practicability and benefits, as shown in those professions which have installed it, would seem to insure its success in engineering.

The following would do much toward remedying the evils which at present invest the profession and its practice:

1.—Registration of all; present reputable and recognized engineers to be exempt from any test;
2.—Licensing all who desire to enter practice in the future;
3.—Minimum standard requirement of preparatory education to be the basis of such license;
4.—Supervision of, or recommendation to, technical schools;
5.—Delegation of authority by the State to the Society to regulate and enforce such registration, licensing and supervision;
6.—Enlargement of the Constitution of the Society to comprehend such action;
7.—Uniform technical courses of a modern and practical kind;
8.—Uniform entrance examinations;
9.—Change of the Society's Constitution to set the example and to exert the influence that would naturally result;

* The article from which the above is taken, and the draft of the proposed bill, may be found in *The Engineering Record*, January 26th, 1901, p. 88.

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10.—Schools and reputable engineers, in or out of the Society, should join to place the profession on a healthy basis.

This Society, the foremost technical society in America, should take the initiative. It should appoint a committee to investigate the present methods and conditions of preparatory education and qualifications for the practice of civil engineering in America, and report to the Society the result of its examination, with such recommendations for improvement as it deems advisable, with a view to the taking of such further steps by the Society as may be necessary and feasible to regulate and limit the practice of civil engineering to those qualified by preparation, competency, responsibility and character, and to elevate the profession to as high a standard as possible.

Mr. Rafter.

GEORGE W. RAFTER, M. AM. SOC. C. E. (by letter).—This question is a broad one, and opens up the entire field of present practice in technical schools. It seems to the writer that the best preparatory education for the civil engineering profession is that which best prepares for the profession, but the difficulty in this statement of the case is to know what does best prepare. Individual idiosyncrasy is so important that what is best for one person may not be best for another, and consequently the personal judgment of the instructor must come in to decide what is best for each particular case.

From this point of view, large schools are a mistake—indeed, if engineering schools did not number more than 100 or 200 pupils, assuming that the class of instructors was up to the mark, there would be a distinct gain. At the large schools, there is so little personal contact between instructor and instructed that the student is practically on his own resources, and if he has within him that which makes an engineer anyhow, there is really, for him, very little value in the technical training—the most that can be said is that he may get to work sooner, which is a much less important point than is generally assumed. A man's work is not measured by years, but by quality, and there are many men whose important work has all been compassed within a few years.

The writer supposes that it is within the experience of everybody who has studied at a technical school that, during the first year or two of practical work, he is chiefly engaged in unlearning the things learned there and during the next year or two he mostly forgets the things learned—at any rate, so far as mere memorizing is concerned. There remains, therefore, for the average student nothing but the training; and this question really narrows itself to, What is the best method of broadening the mind so that one attains comprehension? We return, therefore, to the original propo-

sition, that the best preparatory education for the civil engineering profession is that which best prepares for the profession, that the best education for one individual may not be the best for another, and that, therefore, engineering schools should number only a few students who, under the personal supervision of capable instructors, would receive that which best suited each individual's needs. This would make an ideal engineering school, and probably the nearest approach to this was the apprenticeship system of seventy-five years ago, where, provided the instructor was faithful and earned his fee, the final product made better engineers than the average of those turned out by the technical schools of to-day. Mr. Rafter.

EDGAR MARBURG, M. AM. SOC. C. E.—The subject is so comprehensive that an exhaustive discussion of any single phase of it would consume much time. The speaker, therefore, proposes to refer briefly, and somewhat informally, to the vital element in engineering education—the teacher. Mr. Marburg.

The development of engineering schools within recent years, though sufficiently remarkable, may be regarded, after all, as only the forerunner of an educational movement, the full magnitude of which no one, perhaps, can adequately foresee. The attendance at engineering schools has been increasing by leaps and bounds; and through State aid or private beneficence, many of the schools have been put in possession of excellent facilities. There remains, however, a certain important element of weakness, namely, the teaching element. It must be apparent to every careful observer that the teaching branch of the profession needs strengthening. Though we either have, or are rapidly getting, the ships and guns, in the way of buildings and equipment, we need more men and better men behind the guns—men of proven ability of the highest order. The field of engineering teaching has not proven attractive enough in the United States to enlist a sufficient number of men of the highest caliber. Nor is it surprising, therefore, that the teachers of engineering, broadly speaking, do not hold the same high position in the esteem of the profession as do their colleagues in other professional schools. The large influx of students into the technical schools within recent years has served to make the problem a more serious one, and its solution all the more pressing.

The need of more high-grade teachers in the engineering schools is indeed so apparent, the logic of the situation so obvious, that the speaker believes it to be only a question of time—and, he hopes that time will be comparatively short—when this need, too, will be adequately supplied. In any movement to that end, however, the loyal, active and united support of the profession, exerted through its leading organizations, would prove not only helpful, but well-nigh indispensable. The time is opportune, in the speaker's judgment,

Mr. Marburg. for this Society to co-operate in this matter by authorizing the appointment of a special committee to consider and report on the present status and needs of engineering education in the United States. The speaker proposes, therefore, to introduce a resolution to that end at the proper time.

Mr. Williams. GARDNER S. WILLIAMS, M. AM. SOC. C. E.—This problem of the proper education for the engineer is one, it is needless to say, which is very prominently before the speaker at the present time, and his doctrine is this: First of all, the civil engineer must understand the English language, and the prime essential of his training is that he shall acquire that understanding by the best and most expeditious means that can be discovered.

It is quite possible that for some the best path may be along one road, and for some it may be along another, but English is the foundation, whatever the ultimate requirements may be. Beyond that it must be remembered that to-day the engineer is becoming recognized as belonging, not only to the learned professions, but to the most learned profession, and he should be a leader of thought in the community in which he resides. In order that he may be such a leader, he should be familiar with the history of his country and the history of civilization. History, therefore, should play an important part in the preparatory education of the engineer. He should also understand the principles of common law, as well as those of the law of contracts, the functions of public corporations and of governmental agencies. He should also be thoroughly versed in physics and mechanics, and the speaker would emphasize the statement which has already been made, that what is needed is not the learning of the textbook in detail, but the learning of it in its application to the world at large—the power to apply the things which have been learned. In other words, the essential part of the engineer's training in college, if he goes into the technical school, should be in design. He should be taught to apply the principles which he has learned in the classroom; and, to the speaker's mind, those schools which are devoting the most attention to the designing of engineering work are the ones which are best fitting their students for the demands that will be made upon them five or ten years after they are out of college. Not that they should learn the design of details, but that they should learn the principles upon which all correct design is based.

There has been too much tendency of late—it is, fortunately, not so marked at present as it was four or five years ago—to develop manual training at the expense of other education, in short, to produce skilled mechanics, and many schools are devoting much attention to shop work with the idea of producing men who can go into a shop and receive perhaps as much as $4 or $5 per day upon

graduation; and who have the prospect of getting that for the rest of their lives. The speaker does not understand that it is the place of the university to fit men for that particular occupation. It seems to him that, if the student is going into the shop, all he should attempt to do—all he has time to accomplish in a college course—is to learn in general what is to be done, and what can be done. It is not necessary that he should be able to do it himself; it is not worth while to spend the time necessary to learn that. That time can be more profitably utilized in other ways. Mr. Williams.

There was a period, not long ago, when practitioners demanded that young engineers coming out of college should be able to do something immediately. Our railroad friends said, "Your college men are no good: they do not know as much as the man who works up from the shop or the chain." They do not, as far as to-day or to-morrow is concerned, but the time is rapidly approaching when their value will be realized more fully by the railroad men than it is at present. A young man can get a world of experience in the five or six years of his life after he has come out of college, and he will get it, or he will drop out of the profession; but, in his strenuous efforts for a place in the world during those five or six years, he will not get that training in the essentials of Engineering which the college education should give.

If a student has absorbed his college training, has put it away where it will not go from him, although for the first three or four years out of college he may believe that he has wasted much valuable time, though he may talk of his professors as fossils or impracticable men, nevertheless, 5, 6 or 10 years afterward, he will come to that position in his profession (after he has acquired that training and experience which all must have in order to succeed), when he will begin to see the usefulness of those courses which he regarded as drudgery; then the heads of those who have had brains enough to retain that instruction will be seen rising above those of the rank and file of their fellows.

The duty of the teacher of Engineering is to prepare the student for the position he must fill, not to-day nor to-morrow, not next week nor next month, but 10, or 15, or 20 years from now, when the engineering students of to-day must be the leaders in the Engineering profession.

Olin H. Landreth, M. Am. Soc. C. E.—Those members of the Society who attended the Engineering Congress at Chicago in 1893 will doubtless recall that the Committee of Arrangements divided that Congress into several sections, one of which was on engineering education, and that of all the six or seven sections which met simultaneously during the week none was so generally well attended, and none had its interest so well sustained. It will also Mr. Landreth.

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be remembered that, as the outcome of those sessions, there came to be felt so strongly the need of more time and attention to the subject of engineering education than this Society was able to give at its annual meetings and conventions, that a new society, the Society for the Promotion of Engineering Education, was then established and has become one of the most important engineering and educational organizations, and one which occupies an exceedingly important and influential relation to the entire engineering profession. As a charter member of that society, it is a matter of gratification to the speaker that the American Society of Civil Engineers has again thought the subject of engineering education sufficiently important to devote a considerable portion of one of its sessions at this Convention to the discussion of two phases only of the general subject.

The two important and closely related topics covered by the title have been so well presented by Professor Swain that it is not the speaker's intention to do more than refer to one or two points.

1.—The first point to which attention is asked deals with the relative value of the "successive" as compared with the "simultaneous" method of engineering education; that is, In the education of an engineer, is it better for the young man to complete his general education before taking up his technical training? It is not necessary to state that the engineer of the present and of the future needs, not only intensified technical training, but also broad, general, cultural training. No debate on this proposition is assumed to be necessary. The question here offered for consideration is: Should the young engineer complete his general training before beginning his professional studies, or should the two be carried on simultaneously? The remark is frequently heard that a young man intending to follow engineering should first complete a general college course and then enter the professional engineering school. Some effort has been made in a number of cases to ascertain just why the successive order for taking the two kinds of training has been stipulated, and in every instance examined it has been found to have originated, not from a critical comparison with the simultaneous method, but in the general assumption that there is but one way to acquire both kinds of training, and that is to take them in tandem, or, to use an electrical comparison, to take them in series rather than in parallel. No doubt the general custom followed by students of theology, law and medicine has been largely responsible for the general impression that the same plan should be followed in engineering. Another and a valid reason has existed, but is fast disappearing. In the past the college and the professional engineering school have not generally been component parts of the same institution, and thus have not been in close proximity, but separated. This has made the successive

method necessary. With the modern university, however, comprising academic and professional schools closely contiguous, the foregoing reason does not exist. Both the successive and the simultaneous methods, therefore, are now generally possible, as far as the contiguity of the college and the professional school is concerned. Mr. Landreth.

The advantage to an engineering student of acquiring his general college course and his technical training at the same time will now be considered. The profession of engineering demands of those who follow it successfully peculiar and unusual qualifications. Integrity of character, a capacity and inclination for hard work, power to overcome difficulties, to meet emergencies and to initiate and execute along definite, preconceived lines, and a mind trained to critical, analytical and constructive processes, are certainly not the least of the engineer's qualifications. To develop these qualifications, and especially the analytical and constructive faculties, under the best conditions, requires that the candidate be placed as early as possible under influences and in an atmosphere favorable to this development. It is no criticism of academic training that the above conditions exist to a higher degree in the technical school than in the general college; and it is desirable, therefore, that the student should enter the technical school as early as possible, and thus, while prosecuting his college course, in parallel, secure the stimulus and inspiration furnished by the definiteness of purpose of the technical course and its atmosphere of exact, critical and constructive ideas. When a student completes his college course before entering on his technical training, which latter may be presumed to require two years, his habits of thought have been largely formed, and his mind does not adapt itself as effectively to the habits and methods of exactness and definiteness of objective which are so essential to the successful engineer. Moreover, several of the leading lines of subjects which the technical course must contain require for their best treatment, not only a proper sequence, but also adequate time for proper mental assimilation. The educational principle of unconscious cerebration is here important. The mind requires time for the fullest assimilation of the ideas of an abstruse subject. To compress the numerous and intimately related technical subjects into two years' time cannot but interfere with the proper sequence of topics and also merges so closely on the evil of cramming as to impair seriously the educational value of the course.

An extended and somewhat careful study of the problem, covering an experience of several years, both on the side of the teacher and of the practitioner, leads the speaker to the conclusion that the following programme comprises in general the best preparatory education for the civil engineering profession for the student who is able to take a full college course in addition to his technical training:

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*First.*—Graduation from a high school or a school of equal grade, which will fit a man for entrance to college and also to the better grade of engineering school.

*Second.*—If a student can secure the opportunity or can devote the time, he should then spend one year, in a subordinate capacity, in connection with some extensive engineering enterprise or undertaking, preferably where a variety of work is being carried on. How subordinate or poorly paid the position matters less than that it be one from which the young man will have an opportunity to observe and comprehend the workings of the enterprise, and one where he will be able to acquire a feeling of responsibility for the performance of his duties, and to feel that he was a part, if even a very small part, of the enterprise.

*Third.*—The careful selection of a college and a technical school which not only furnish superior courses of their respective kinds, but which are so situated, either under the same or under different organizations, that the student may enter both simultaneously and arrange his course, extending over six years, so that the two lines of training may be judiciously and systematically laid out and carried along together. By this plan the desired sequence of subjects may be secured, and the necessary time for mental assimilation of the more abstruse subjects obtained, and both sides of the man developed simultaneously. It is not to be supposed that the time proportionally allotted to each of the two lines of training would be the same throughout the entire course. During the early years the general training would predominate, with enough of the technical, however, to lay an early foundation for technical thought and appreciation and to extend sufficiently in time the several topical lines of technical subjects. In the latter years of the course the technical subjects would necessarily predominate, and the student would come to them with the all-round development and the breadth of view which the general training had given him.

The important question as to what each of the two courses should comprise is too extensive for discussion at this time. In the speaker's opinion, however, the college course which is best suited to the needs of engineering students is the old-line classical course, with Greek omitted and its place taken by increased work in history, economics, sociology and æsthetics. For the engineering course, the increasing importance of better and broader training in the fundamental technical studies leaves little legitimate opportunity for specialization in the two years properly assignable to the technical portion of the course. A thorough mastery of the fundamental principles of those subjects which should be familiar to every engineer, whatever his specialty, leaves no time in the course for narrow specialization; that should come

later. Technical specialization in an engineering course undoubtedly leads to more immediate utilitarian results, but invariably at the sacrifice of breadth of training and future efficiency. The profession appears to be already over-supplied with the specialist whose narrowness of training and whose consequent unfamiliarity with the fundamental principles of the neighboring branches of his own profession, and frequently with life itself, impair his judgment and limit his usefulness to society. It is bad designing which increases the altitude of a structure by materials needed in the foundation. The Eiffel Tower, with its broad base, symmetrical and graceful outline and superior altitude, furnishes an excellent model in simile for the training of an engineer. Mr. Landreth.

2.—Turning to the second question of this topical discussion, *viz.*: "Is Technical Training the Best Education for Executive Work?" it would seem from Professor Swain's treatment of the question that by the term, executive work, he had in mind administrative management. With this interpretation it would seem that the answer must depend very largely on what kind of administrative work is contemplated. It is possible to mention some lines of administrative work in which a technical training would not be of especial value and might even be harmful, if it had absorbed time otherwise available for a training more pertinent and directly related to the administrative work in question. There are, however, a great number of lines of administrative activity, and, under modern conditions and tendencies, the number is rapidly increasing, in which a technical engineering training forms an important if not an essential part of the preparation. In fact, engineering is coming to comprise more of administrative work than ever before. The work of the modern engineer may be classified or analyzed into the following divisions:

Investigation,
Design,
Execution, and
Administration.

Before beginning any enterprise or undertaking the engineer investigates conditions and circumstances to determine the possibilities and limitations surrounding the undertaking. With the result of this investigation before him, if favorable, he designs his enterprise, his structures, his methods and accessories. He then executes the undertaking from the designs; and, if the enterprise be one involving technical skill in its management, he or his brother engineer proceeds to administer it. It is only recently that the fourth duty, that of administration, has fallen to the engineer; formerly the business man took this part together with a

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majority of the credit and emoluments of the undertaking. Since technical skill has now become an essential adjunct of the administration of many classes of industrial and even business enterprises these questions have arisen:

*a.*—Shall the administration be divided between a business man and an engineer, or shall there be but one administrator?

*b.*—If but one, shall the business man be given an engineering training, or shall the engineer be given a business training?

The principle, accredited to Napoleon, that one poor leader is better than two good ones, in recognizing the necessity of unity of responsibility, may be accepted as representing one of the important principles of modern administrative systems, *viz.*, the principle of undivided responsibility.

If we are to have but one administrator possessed of both business and technical skill, economy clearly dictates that it is better to give the engineer the business training than to attempt to give the business man the technical training.

If the engineer is to become an administrator, the question at once presents itself: How can he best acquire his administrative ability? Is it best that he should acquire it entirely through experience, without any direct aid from the schools; or is it possible to include, in his technical course of study, instruction which shall directly aid him in developing the administrative capacity after beginning his professional work?

After a careful study of the foregoing question covering several years, including observations from experience, the speaker is strongly inclined to believe that it is possible to include in the student's course of study, instruction and training which will help to lay the foundation for the development of administrative capacity after leaving school. No one of authority will claim that the engineering school makes engineers, nor that the law school makes lawyers, and yet, to-day, few will deny that the technical training is of very material assistance in making engineers as well as other professional men. What is true of the course of study at large is also true of its component parts; a study of the principles directly underlying drafting, surveying, mechanics and materials substantially assists a man to become a draftsman, a surveyor or a structural designer; and it is also believed that proper instruction in the principles of proper subjects during the student's course of study may also be of direct value toward giving the engineer ability in the administrative direction later. Of course, nothing more than fundamental principles should be undertaken, but these should be well taught. Any attempt to give bare information, methods or procedure, beyond what is useful in explaining and making

clear the principles, would doubtless result, as in most other tech- Mr. Landreth.
nical subjects, in loss of time and disappointment.

In addition to the regular courses in history, economics, sociology and political science, which the engineer's general college course should include, the particular subjects which appear to promise the most useful results, as further aids in laying a foundation for administrative development, would appear to be:

(1).—The elements of law in general and of the law of contracts, agency, property, bailments and corporations, in somewhat further extension;

(2).—The principles of finance and financial operations, with applications to the monetary, credit and exchange systems in vogue;

(3).—The principles of accounting in general, and further as applied to transfer accounts, stock accounts and cost-keeping systems;

(4).—The principles of business administration, more especially as applicable to organization, dicipline and effective execution.

With a framework of principles such as the foregoing or other equivalent subjects, firmly established, the young engineer on going out into professional work would have a substantial foundation on which to build, and would understand and absorb much more effectively and rapidly the facts and conditions of his experience and would assimilate them more readily in the development of his administrative capacity.

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# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## SEWAGE DISPOSAL.

An informal Discussion at the Annual Convention, June 28th, 1906.*

SUBJECT FOR DISCUSSION:

"The Advance in Sewage Disposal."

BY MESSRS. G. C. WHIPPLE, E. KUICHLING, GEORGE W. RAFTER, W. S. JOHNSON, J. P. A. MAIGNEN, CLYDE POTTS AND R. WINTHROP PRATT.

Mr. Whipple.

G. C. WHIPPLE, ASSOC. M. AM. SOC. C. E.—During the last few years the advance in sewage disposal has been conspicuous and most gratifying. It has been due not so much to the introduction of new methods of treatment as to a thorough trying-out of methods already known. Theories recently advanced have been put to practical test, and the published reports of successes and failures have helped much to establish in the minds of engineers clearer conceptions of the general principles involved. Through the mist of confused notions about septic tanks, contact beds and trickling filters, primary systems and secondary beds, and through the haze of bacteriological mysteries surrounding aerobic and anaerobic processes, experience and common sense are forcing their way and developing rational and practical methods of treatment. Of the new ideas, some have been already cast aside as unsatisfactory, impractical, or too expensive, while others seem likely to sink into innocuous desuetude before many years. A few, however, have proved of such substantial benefit that they justify all the ex-

* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

A number of discussions on this subject, presented at the Convention, were not received in time to permit of preparing them for this number of *Proceedings*. They will appear in the *Proceedings* for September.

penditure of time and money which has been devoted to the study of the subject by many investigators working in many lands. Mr. Whipple.

England has taken the lead in these matters, and it is there that one must go to find the latest developments in the art. If one asks the reason for this, a fitting reply is found in the old adage: "Necessity is the mother of invention." The English rivers are small, the English cites are large and numerous, and the amount of manufacturing carried on in them is very great; consequently the streams are badly polluted, and the need of sewage purification works is pressing. Furthermore, the soil of the country is not well suited for land treatment of sewage, and in consequence English engineers have been forced to adopt other methods. This has stimulated their ingenuity, and given rise to many modifications of chemical and bacterial processes. In England, therefore, one can see more and learn more of sewage disposal at the present time than anywhere else in the world.

French and German sanitarians have not been idle, however, and the experimental work now being carried on is sure to be followed by the construction of important works suited to their local needs.

In America the theory of sewage purification processes has been assiduously studied at a number of testing stations: notably at the Lawrence Experiment Station of the Massachusetts State Board of Health; at Columbus, Ohio; and at the Massachusetts Institute of Technology. For the most part, the results of these studies agree with those made in England at Manchester, Birmingham, Leeds, Bradford, and elsewhere. Few important sewage disposal works have been put in operation in the United States during recent years; in fact, except at Worcester, Mass., and at Providence, R. I., there are no sewage purification works of the first rank in this country, but a large plant is under construction at Columbus, Ohio, and projects are being considered for Baltimore, Md., Paterson, N. J., and elsewhere, while many small plants have been built and are in operation.

One of the signs of advancement in the art of sewage disposal is the general recognition of the fact that an economical method of purification must proceed by distinct stages. This has resulted in the division of processes into certain groups, the separation of which will add much to a clear insight of the subject.

### Classification of Methods of Sewage Disposal.

The processes involved in sewage purification may be divided into three principal groups:

1.—Preparatory Processes,
2.—Purification Processes,
3.—Finishing Processes.

Mr. Whipple. In one sense these are all purification processes, as they all tend to make the liquid sewage less offensive. Each group has many subdivisions, and the various methods are used in all sorts of combinations. The variations are chiefly for adapting the treatment to local conditions, but too often they are due to the idiosyncrasies of the designing engineers or to the pernicious activities of companies owning certain patent rights.

### Classification of Methods.

| 1. | 2. | 3. |
|---|---|---|
| *Preparatory Processes.* | *Purification Processes.* | *Finishing Processes.* |
| Screens, | Sub-surface irrigation, | For Clarification: |
| Roughing filters, | Broad irrigation, | Sedimentation, |
| Detritus tanks, | Intermittent filtration, | Coarse filtration. |
| Plain settling tanks, | Contact beds, | For Bacterial Improvement: |
| Chemical precipitation tanks, | Sprinkling filters. | Land treatment, |
| Septic tanks. | | Sand filtration, |
| | | Mechanical filtration, |
| | | Disinfection. |

In sewage purification there is a gradual separation of the solid matter from the liquid; the sludge is ultimately disposed of in one way and the more or less purified liquid sewage in another. Thus two more general groups must be provided, for convenience of discussion, namely:

4.—Disposal of Sludge,
5.—Disposal of Purified Effluent.

To these may be added a sixth, namely:

6.—Disposal of Storm Water.

It is not the speaker's intention to describe each of these processes in detail, but rather to speak of certain observations, in connection with some of them, made during a recent visit to England and the Continent.

### Preparatory Processes.

Raw sewage cannot be economically purified by the direct application of any single process, on account of the complex character of its constituents. A liquid which contains substances both organic and inorganic, in which a part of each is in solution and another part in suspension, and in which the suspended particles vary in size from banana skins down to the ultra-microscopic, a

liquid which is continually altering in composition, and in decomposition as well, and is continually varying, not only in quality, but in quantity, cannot be easily rendered free from its obnoxious ingredients. Some form of preliminary treatment, therefore, is always used. This may be a mere screening or filtering out of the coarse suspended matter, or it may be a settling out of the heavier particles in sedimentation tanks through the influence of gravity. Chemical or even biological agencies may be made to assist the action, but, essentially, all the preparatory processes are of a physical character. They have for their object the removal of suspended matter in order that the remaining liquid may be more easily purified by subsequent treatment. Mr. Whipple.

*Screening.*—Little need be said about screening, except that in large plants the use of revolving inclined screens with automatic cleaning devices has rendered this initial step in the process more effective than the old-fashioned bar-screens, or cage-screens, which were lifted and cleaned by hand. At Birmingham there is an inclined revolving screen which is operated by an undershot water-wheel placed in the channel conveying the sewage. It works under a 6-in. head, the flow being about 3 000 000 gal. a day. The accumulations on this screen, which has a ¼-in. mesh, are dropped into a gutter, where an endless screw pushes them to one end and deposits them in a cart. Engineers appear to be taking a new interest in the matter of screening; finer and more efficient screens are being advocated, and in the near future important developments may be looked for. In many places the screened material is burnt under boilers, mixed with coal, or in some cases with the city garbage, and the power generated is used in various ways around the works.

*Roughing Filters.*—Roughing filters are used but little, although they have been studied experimentally in a number of places. As a means of removing suspended matter they are far less economical and much more troublesome than settling tanks. Where they have been used it has generally been in connection with other forms of preparatory treatment. At Salford, for instance, where, in the opinion of the engineer, they form an essential part of the preparatory process, they are placed between the chemical precipitation tanks and the sprinkling filters.

*Detritus Tanks.*—The use of detritus tanks, grit chambers, catch-pits, roughing tanks, or settling tanks at high velocities, as they are variously called, is very common. Their usefulness depends largely upon the character of the raw sewage. When the quantity of suspended mineral matter is large, as it often is in cities sewered on the combined system, or in places where the quantities of manufacturing waste are large, detritus tanks, arranged so that they may be easily cleaned without interrupting the flow of sewage, are

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advantageous. They are also helpful in small plants where septic tanks are used. Under certain conditions, where the screening process is efficient and sedimentation takes places in a manner to be described, the detritus tank may be dispensed with. In England much thought appears to have been given to the design of these detritus tanks. In Glasgow, the sewage, after passing the screens, flows through a long catch-pit of semicircular cross-section. The sludge is removed from this at short intervals by an electrically-driven bucket-dredge. This moves over the pit on a track, lifts the sludge and conveys it to a car on a parallel track beside the dredge. All this is done, of course, without interrupting the flow of sewage.

The time allowed for settlement in detritus tanks varies from a few minutes to several hours. The sewage often reaches the works in a septic condition, and, were it not for frequent cleaning, the sludge would undergo septic action which would tend to interfere with the usefulness of the tank for sedimentation at high velocities.

*Plain Sedimentation.*—Plain sedimentation at low velocities, unaccompanied by the use of chemicals or by septic action, is but little used in England, although in many, if not in most, settling tanks, the chemical and biological changes are of secondary importance. In any of the preparatory tank processes the settling of the suspended matter by gravity is the controlling function. Within the last few years there has been a reaction against the too exalted ideas of bacterial agencies, as originally set forth, and a recognition of the fact that the separation of sludge from sewage is essentially a physical problem. Plain sedimentation, modified as mentioned later, is likely to play an important part in the future.

*Chemical Precipitation.*—Twenty-five years ago chemical precipitation was very largely used in England. Lime, or lime and iron, or alum, were considered necessary accompaniments of the settling process. In many cases this chemical precipitation was the only means of purification used, the tank effluent being discharged directly into river or sea, or turned upon land. This method, to a very great extent, has been superseded by other modes of treatment, but even to-day there are some large cities near the coast which adhere to the old system; notably London, Glasgow, and Dublin, the last-named city having new works just about to be put in operation. London has nearly outgrown her works at Barking and Crossness, and although the efficiency of the process is said to be satisfactory, yet the volume of sewage has become so large and the quantity of organic matter discharged in the tank effluent is so great that the water of the Thames becomes almost exhausted of its oxygen during the summer when the stream flow

diminishes. This is a condition which the authorities recognize will give rise to a nuisance if long continued. In the near future there will be needed some process which will yield a purified effluent better than can be obtained by the use of chemical precipitation alone. On account of the magnitude of her sewage problem, London has taken a conservative course, and has preferred to adhere to the present method, rather than embark upon some scheme which has not been tested by experience. This seems to have been a wise policy. The early experiments at Barking, made by Dibdin and his successors, showed the efficiency of contact beds as a means of purification, and have had far-reaching effects on the general problem; yet, in view of later studies and experience, it is questionable whether the adoption of this method for treating all the London sewage would have been the most economical one. The Thames Conservancy Board and the London County Council, in view of what has already been done, can probably be relied upon to see that the river does not become offensive. Nothing is more surprising to an American engineer, familiar with the Chicago, Passaic, or Blackstone Rivers, than to find that the Thames, flowing through the heart of the largest city of the world, is clean—no offensive odors, no unsightly scum, no litter on the shores. It is an object lesson in the art of inspecting which may well be studied by American officials. Mr. Whipple.

At Glasgow the condition of the Clyde is rather worse than that of the Thames at London. This, in a measure, is due to the fact that not all the sewage of the city is purified, but it has already become clear that chemical precipitation alone will prove unequal to the task of keeping the waters of the Clyde permanently clean, and it is somewhat surprising that the new works now under construction should be practically a duplication of the old plant. The present plants appear to be well operated, however, and to be doing all that can reasonably be expected of them.

The use of chemical precipitation as a preparatory process, however, is quite another matter, and instead of going out of use it seems to be gaining favor, especially in those cities where the quantity of manufacturing waste is large. In order that contact beds or sprinkling filters may operate satisfactorily and economically, the quantity of suspended matter must be reduced to a minimum, fats must be kept down, and the colloidal substances precipitated to as great an extent as possible. In some cases this appears to be accomplished more easily by the use of chemicals than by plain or septic sedimentation. The sewage of Bradford may be taken as an illustration of this, although it is an exceptional case.

Bradford is a great manufacturing city, the center of the

Mr. Whipple. woolen industry. All the trade wastes, after settling, go into the sewers. The sewage is probably the strongest and most difficult to treat of any in England. The total quantity of solid matter is about 1 800 parts per million, of which 1 100 parts are in suspension. The quantity of fats is about 650 parts per million. Bradford's present chemical precipitation works are completely outgrown, and extensive studies have been made during the last few years to determine the best mode of treatment. These studies have shown that the sewage cannot be prepared for treatment on contact beds or on sprinkling filters by either plain or septic sedimentation. Even with the septic period prolonged to two or three days the results were unsatisfactory. The use of chemicals in such a case seems to be absolutely necessary. The chief difficulty in treating the sewage is due to the excessive quantity of fats present. For this reason sulphuric acid has given better results than lime or other chemicals. The acid decomposes the soaps and separates the fats, part of which rise to the surface, where they are skimmed off. The remainder settle with the sludge, from which they are ultimately recovered by steam pressing and distillation. This grease recovery process is more extensively carried on at Bradford than anywhere else in England, and is said to be practically self-supporting. Some sludge, instead of being used for grease recovery, is mixed with coal and burnt under the boilers. The plans for the new works are not fully formulated, but it is understood that in general the process will consist of chemical precipitation followed by sprinkling filters.

At Rochdale, also, chemical precipitation is used as a preparatory treatment. Here, also, the sewage contains wool waste, and sulphuric acid is used during the day. Sulphate of alumina is also used. At Hyde septic tanks are now followed by sprinkling filters, the use of chemicals having been given up. A return to the use of chemicals during the day is being contemplated, however, as a part of the preparatory process.

The use of "alumino ferric" or "ferrozone," both of which are merely crude forms of sulphate of alumina, is exceedingly common in small plants. Thus, within the jurisdiction of the Mersey-Irwell Joint Committee, there are 70 out of 98 works at which alum, or some other chemical, is used in connection with preparatory sedimentation processes.

Although in few instances have septic tanks been given up for, or been supplemented by, the use of chemicals, engineers and inspectors appear to be coming back to the idea of using precipitants in connection with the preparatory treatment of sewages heavily laden with manufacturing wastes.

*Septic Sedimentation.*—The septic tank is still the subject of

more or less controversy in England. It still has its enthusiastic advocates and opponents, but present-day discussions are tempered with reason, and are based more on fact and less on theory than in earlier days. One thing seems to be certain, the septic tank has earned its right to exist. It has not accomplished all that its originator first claimed; it does not "do away with sludge"; it does not fit the liquid sewage for further purification; it is not without nuisance. But, on the other hand, if it does not entirely eliminate sludge, it reduces its quantity, and alters its character; while, if it does not help future treatment of the liquid sewage, it at least does not hinder it. Its chief advantage is its effect on the sludge; a disadvantage is the frequent nuisance from odor. Mr. Whipple.

That the septic tank is a nuisance in many places, appears to be well established. On this point the opinions of the inspectors and of residents near the works are more to be trusted than those of the sewage-works managers, although even they often complain of bad odors. The extent of the nuisance depends altogether upon local conditions—the character of the sewage, the size of the plant, the period of septicity, the nature of the subsequent purification process, the topography of the surroundings, the weather conditions, etc. It would be unjust to suppose that the septic tank is always and necessarily a nuisance to neighboring residents. Often it is not.

The septic process is an anaerobic or putrefactive one, and putrefaction, of course, involves the formation of odoriferous gases and offensive substances. Whether or not these become a nuisance depends upon their amount and the opportunity which is given them to escape into the atmosphere. Covers for septic tanks, which were part of the original idea, prevent, to some extent, the spread of bad odors, but covers are not necessary to the efficiency of the process, are expensive, and even dangerous on account of the explosive character of some of the gases liberated. Already several fatal accidents have occurred in England. Open septic tanks are often free of nuisance. In winter the septic action is not as vigorous as in summer, and the products of decomposition are less, while in summer the septic tanks are sometimes covered with a firm dense scum, which to a certain extent prevents the gases from diffusing into the atmosphere.

As an illustration of the density of the scum the speaker might mention the case of a small septic tank which he saw at Birmingham, in which grass was growing on top of the scum. While commenting on this and on the entire absence of odor, the manager's dog strolled leisurely out on the tank and crossed to the other side. In fact, it is said that at Leeds men have crossed over the septic tanks on the scum.

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When the odors do not escape from the tanks at the surface, the liquid effluent is likely to be offensive, and if this effluent is sprayed into the air or poured in thin films over a sprinkling filter, full opportunity is given for the liberation of bad odors. In fact, it may be said that the most serious nuisance arising from the septic tank is when it is used in connection with a sprinkling filter. Sanitary inspectors and representatives of the Local Government Board and the Royal Commission on Sewage Disposal were all emphatic in expressing their ideas as to the amount and frequency of bad odors due to this combination. From conversation with these officials, and from personal observation, the speaker gathered the opinion that under English conditions sprinkling filters treating septic sewage cause enough nuisance to depreciate substantially the value of property for residential purposes within a radius of one-quarter of a mile from the works, in the case of small plants, or almost half a mile from the works, in the case of large plants. If the sewage works are situated in a valley down which the prevailing winds blow in summer, the nuisance occasionally extends to greater distances in certain directions. Every plant must be judged for itself, however, and the foregoing estimate has only a very general application. In America, with more dilute sewages, the circles of influence might be less extensive. Meteorological conditions have a very important effect on the transmission of bad odors. On warm, muggy days, with a moderate breeze, a sewage plant may be a decided nuisance, while during clear, cool weather it may attract no attention whatever. This fact is too often overlooked by visitors to sewage works.

Trade wastes sometimes tend to increase the disagreeable odors of septic sewage. This is particularly true of brewery and distillery wastes, which contain large quantities of organic matter, sulphur compounds, starch, etc. The period of septicity is perhaps even more important. Much is heard of late about oversepticity, and, unquestionably, with the strong English sewages, the 24-hr. period required by the Local Government Board is often too long. With the weaker sewages in America, and with septic periods properly adjusted, the bad odors due to the spraying of septic sewage may be somewhat mitigated.

Practical experience with the septic tank has shown that it tends to reduce the quantity of sludge. The suspended mineral matter in sewage, of course, is unchanged in the septic tank, although much of it settles through the action of gravity. A large part of the organic matter is also unaffected by the bacterial process, or, at any rate, remains in the tank as organic matter, though perhaps modified in character. Some of the organic matter in suspension, however, is liquefied or gasified, or, to use a common term, is digested. The quantity of digested matter may be taken ordi-

narily as between one-quarter and one-third of the suspended solids, and therefore the quantity of sludge is lessened by that amount. Some engineers believe that a 15% saving of sludge is all that can be expected of a septic tank through digestion. Much, of course, depends upon the character of the sewage. Apparently, domestic sewage is better adapted to the septic treatment than sewages rich in trade wastes. Mr. Whipple.

Long standing in the septic tank tends to make the sludge more compact. Speaking roughly, it may be said to reduce the volume from one-third to one-half. The character of the sludge becomes altered. This was strikingly illustrated to the speaker by Mr. John D. Watson, Engineer of the Birmingham Sewage Works. With a long pole he withdrew portions of sludge from a settling tank which had been in operation only one week and from a septic tank which had not been cleaned for three years. The former was fibrous, gray in color, and had a marked offensive sewage odor, while the latter was black, granular and almost odorless. Mr. Watson stated that the septic sludge could be spread upon land without offense, while the application of the sludge from the plain settling tank gave rise to very disagreeable odors. To do away with the latter, he has been for some time in the habit of pumping his settled sludge into septic tanks for further treatment.

Granting that the liquid septic effluent has no virtue, and may be a nuisance when applied to sprinkling filters, and granting that the use of the septic tank has a beneficial effect on the sludge, a logical improvement would appear to be the modification of the manner of using the septic tank so as to maintain the advantage and eliminate the nuisance. This is a matter now being considered by some of the English investigators. The best method of accomplishing it appears to be by the use of plain sedimentation for the sewage and septic treatment for the sludge alone. In other words, the idea is to treat the liquid portions aerobically and the solid portions anaerobically. This is scientifically correct in principle, as the beneficial anaerobic action is concerned with the carbohydrates, which are chiefly in suspension. In no case with which the speaker is familiar has this result been actually accomplished, but in a number of cases the idea has been partially applied. In the case of Birmingham, just mentioned, the sewage passes somewhat rapidly through settling basins which are cleaned at frequent intervals, most of the liquid sewage being allowed to flow to certain septic tanks, while the sludge is pumped to other septic tanks for further digestion. This takes care of the sludge, but it does not leave the sewage unseptic when it goes to the sprinkling filters.

At Hampton, England, Ault and Travis have devised what is called a hydrolytic tank. This is a tank with an upper and lower

Mr. Whipple. compartment. The raw sewage passes laterally through the upper compartment, while the sludge, together with a small percentage of the liquid, settles into the lower compartment, where it goes through the septic process. But in this plant, also, the liquid sewage becomes septic before it is applied to contact beds. In Macclesfield and elsewhere there are tanks for the storage of sludge, where septic action goes on. There seems to be no reason why the separation of the liquid sewage from the sludge may not be made in such a way as to leave the former in a stale, or non-septic condition, so that it may be applied to sprinkling filters with the least possible nuisance.

*Results of Preparatory Processes.*—The object of the preparatory process, therefore, is to remove as much of the suspended matter as possible. It cannot be expected to remove it all. The quantity left in the sewage will depend upon the quantity in the raw sewage and the character of the process used.

Generally speaking, the preparatory treatment should reduce the quantity of suspended matter to at least 100 parts per million, and preferably to a lower figure. In the case of some of the heavy English sewages, this is not always accomplished, even with the aid of chemicals. The more sludge that can be taken out by the preparatory processes without resorting to the use of chemicals, the cheaper will be the cost of the entire treatment. When it is necessary to use chemicals, however, it becomes a nice calculation to strike the most economical balance of parts.

After the preparatory processes, the treatment of sewage is conducted along two lines which must be followed separately, that is, the purification of the liquid sewage containing the residual suspended matter, and the disposal of the sludge.

## Purification Processes.

All processes which essentially alter the nature of sewage are bio-chemical. Bacterial methods of treatment are not new. The changes which took place in sewage by the older methods of subsurface irrigation, broad irrigation, and intermittent filtration were just as much bacterial as the newer methods of treatment by contact beds and sprinkling filters. The only difference appears to be that in the older methods the bacterial processes were not watched, while in the latter they are carefully controlled.

*Land Treatment, Etc.*—There is no need at this time of rehearsing the story of the purification of sewage by land treatment, as all matters regarding irrigation and intermittent filtration are familiar to American engineers. The new ideas relate to contact beds and sprinkling filters, both of which are essentially aerobic*

*In contact beds there may be at times a slight anaerobic action.

processes carried on in comparatively coarse-grained beds, but which differ materially in their manner of operation and in the disposition of the sludge. Mr. Whipple.

Lest the omission of intermittent sand filtration be misconstrued, it may be remarked that, in the opinion of the speaker, this is the most satisfactory and economical method of disposal where local conditions permit it to be used.

*Contact Beds.*—A contact bed consists of a water-tight compartment, generally built of concrete, filled with comparatively coarse material, such as coke, clinker or broken stone, and having, of course, relatively large spaces between the grains. Sewage is applied to it at regular intervals of a few hours until the bed is full, a brief period of rest is given, after which the outlet gate is opened and the liquid allowed to drain away slowly. Then the bed stands empty for a certain period, and the cycle begins again. Contact beds are often operated in series, the effluent from the first being allowed to flow to a second, and the effluent from the second to a third. The secondary beds are made of finer material than the primary beds, and the tertiary beds are still finer. The sewage is generally applied at the top, but in some instances at the bottom. Surface distribution is made by wooden troughs placed in or over the material, or else the material itself is ridged into channels, or "grips" as they are called in England.

The action of a contact bed is partly physical and partly biochemical. If the process is properly carried out, the effluent from the primary beds is fairly clear, and the effluent from the secondary beds almost entirely so. This means that the suspended matter has been left in the pores of the bed. The effluent is also non-putrescent and to some extent nitrified, indicating that bacterial action has taken place. Contact beds have a controlled respiration, air being drawn into the bed as the sewage leaves it. The oxygen thus admitted acts on the suspended organic matter left in the interstices, and under the influence of aerobic bacteria, changes it, or a part of it at least, to the condition of a stable humus with the formation of nitrites and nitrates. When the beds stand full the oxygen may become exhausted, and for a brief interval anaerobic conditions may prevail. It is upon the oxidation processes, however, that the actions of contact beds chiefly depend.

The largest contact beds in existence are those at Manchester, England, where they cover an area of 46 acres. They operate at the rate of about 450 000 gal. per acre daily. There is only one series of beds in use, but it is intended to build secondary beds at an early date. Septic sedimentation is used for the preparatory treatment. The contact method has been in use since 1901. The effluent is discharged into the Manchester Ship Canal. Its quality

Mr. Whipple. has not been up to the standard of the Mersey-Irwell Joint Committee, that is, 1.0 gr. per gal. of oxygen consumed in 4 hr., although the degree of purification has been fairly satisfactory for single contact beds. The effluent from the one secondary bed now operating is good.

At Burnley there are both primary and secondary contact beds, and although the plant is not as large as that at Manchester, it is in some respects a more interesting plant to visit. Here the effluent from the secondary beds is generally within the requirements of the Mersey-Irwell Joint Committee. The plant has been in operation for about eight years.

The rate of filtration of a contact bed depends upon the character of the sewage, the size of the grain, the depth of the bed, the amount of clogging, etc. A common rate in England is 500 000 gal. per acre daily; with weak sewages and with efficient preparatory treatment it may be nearly double this quantity, but with the strong English sewages it is sometimes unsafe to apply more than 300 000 gal. per acre per day. The rules of the Local Government Board prescribe that the rate shall not exceed 325 000 gal. per acre daily for each foot in depth when the effluent is to have subsequent treatment. Double contact beds are required when it is not. Contact beds naturally lose their capacity as they become clogged. After a time it becomes necessary to remove the filtering material, wash off its accumulations, and restore it to the beds. The coke or clinker filling is generally cleaned by washing and screening through cylindrical revolving screens, which separate the material into different sizes. A washing apparatus with suitable conveyors is just as essential a part of a sewage purification works where contact beds are used as is a sand washer in a modern filtration plant. Thus far, those which have been used have been crude and of a temporary character, and there is a chance for decided improvement in their design. The frequency with which contact beds have to be renovated cannot now be determined with certainty, as many factors are involved and the data are as yet insufficient. There seems to be a feeling among English engineers, however, that primary beds operating at average rates on ordinary domestic sewage may be counted upon to last from 3 to 7 years, while secondary beds may last from 8 to 15 years. At Manchester no renewals were made until the beds had been in operation nearly 5 years, and even now they are renewing only one-third of each bed, namely, those parts under the grips, where the clogging naturally is greatest.

Properly operated double contact beds yield effluents which are reasonably free from suspended matter and color, and which are non-putrescible. Many contact beds have failed because they have been overworked or because the regimen of operation has not been suited to local conditions.

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Contact beds have one advantage over other purification processes. Their depth can be varied at will, as their efficiency is not as dependent upon depth as in the case of sprinkling filters. They have been built as shallow as 2 ft. When sewage works are located so that there is little available head, therefore, contact beds are especially applicable. They can be operated, also, with less nuisance from odor than sprinkling filters, especially when filled from the bottom. For small gravity installations, contact beds are useful, as they can be made to operate with comparatively little attention.

*Sprinkling Filters.*—Perhaps the most important advance in sewage disposal during the last few years is the general recognition of the sprinkling filter as an efficient means of purification. This is also called the "trickling filter," "continuous filter" and "intermittent continuous filter." The term "percolating bed" has also been suggested, as well as "spray filter." A sprinkling filter, like a contact bed, is composed of relatively coarse material. Its operation, however, is very different. Instead of being worked on the fill-and-draw principle, the sewage is applied continuously at the surface, either as a spray or in a thin sheet. The outlet gate is kept open, and the sewage trickles down through the bed and passes out of the under-drains, which are made large and open so as to insure a thorough aeration of the entire bed. The process is emphatically an aerobic one. Air is continuously entering the bed with the water, and passing in or out through the under-drains, and sometimes through the sides of the filter. As the liquid flows rapidly through the bed, and as no sewage is supposed to accumulate in the bed, there is really no need of side walls, and in some cases these are omitted, the material being allowed to take its natural slope. More often, however, loose walls of brick or stone are built up to retain the material.

The filtering material is generally coke, clinker, or broken stone. There is some difference of opinion as to the best size to be used. Some engineers prefer what are called "fine-grain beds" in which the diameters of the particles lie between $\frac{1}{8}$ in. and 1 in. Thus, at Hanley, which is perhaps the best illustration of a fine-grain sprinkling filter, the material consists of three equal layers which together make a depth of 5 ft. The coarsest, which is at the bottom, is screened between $\frac{3}{4}$ and 1 in., the middle layer between $\frac{1}{4}$ and $\frac{1}{2}$ in., and the top layer between $\frac{1}{8}$ and $\frac{1}{4}$ in. The material used is known as "saggers," and is obtained by crushing the broken pottery jars in which china is baked. More often "coarse-grain filters" are used, and material screened between 1 and 3-in. screens is very common. Both fine-grain and coarse-grain filters have their advocates, but the latter appear to be generally preferred. Fine-grain filters yield clearer effluents, but, as a result, they become clogged,

Mr. Whipple. while aeration is rendered more difficult. Coarse-grain filters, on the other hand, do not clog as readily, and therefore their life is longer and the ventilation better, but the effluent is more or less turbid.

The application of the sewage to the bed is a matter of great importance, and one which has been carefully studied by English engineers. Many patented devices are on the market for accomplishing it. As aeration is important, the more the applied sewage can be subdivided into small drops the more efficient will be the process. One of the earliest ways of applying the sewage was to allow it to flow through small holes in troughs placed over the surface of the bed. This method has been found to have its disadvantages. The holes are likely to become filled up, and the troughs tend to get out of level, thereby causing unequal distribution of the sewage.

Rotary sprinklers are much in vogue in England. They consist of four arms mounted on a central vertical shaft so that they revolve in a horizontal plane immediately above the surface of the bed. The arms are perforated only on one side, and, the sewage being discharged through them, the apparatus is made to rotate, on the principle of Barker's mill. These rotary sprinklers are now so common in England, especially for small plants, that they have become a characteristic feature of the landscape as one looks from the car windows in certain sections of the country. Some of the largest rotary sprinklers are 120 ft. in diameter, and are operated with power instead of in the manner above indicated. In some cases the end of the sprinkler is carried on a circular track laid around the bed.

Some of the objections which have been raised against the use of rotary sprinklers are that the holes tend to become clogged, and that the wind interferes with their rotation. They also require circular instead of rectangular beds, although in some cases several rotary sprinklers have been placed in large rectangular beds, the dead corners being sprayed from fixed nozzles. The intermittent application of sewage, which is obtained by the use of the rotary sprinkler, is thought by some to have decided advantages.

Instead of using rotary sprinklers, the sewage is sometimes applied to rectangular beds through a perforated pipe mounted so as to travel back and forth laterally. This arrangement is used at Hanley. The pipe is carried at the ends on trucks which run on rails along the sides, and are operated by electricity.

The movable devices appear to be satisfactory for small installations, but cannot be applied to large beds. When filters reach a size of an acre or more, permanent jets give a better distribution of the sewage. The first large plant of this kind to be erected was

that at Salford, England, but the beds which are being constructed at Birmingham surpass it in area. The sprinklers there used are said to give general satisfaction, but the managers say they gradually become clogged, and that it is necessary to clean them out at frequent intervals. The strainers recently devised for the Columbus plant appear to be a decided improvement over any in use in England. The sprays are generally operated under a head of about 4 ft., and the applied sewage usually rises to a height of 1 or 2 ft. above the surface of the bed. Mr. Whipple.

The purification which takes place in the sprinkling filter is due entirely to the action of aerobic bacteria. The suspended matter in the applied sewage settles on the grains, as the liquid passes through, until gelatinous films are formed. Being liberally supplied with air, the organic matter gradually undergoes decomposition, and changes its character, becoming somewhat granular and more like the condition of ordinary top soil. When the accumulation has reached a certain point, films of this accumulated matter break away from the grains and are discharged with the effluent. To a certain extent this process is continually going on, so that the effluent is never wholly free from turbidity, but it has been noticed that there is an unloading of the accumulated sediment at more or less regular intervals. This may be caused by an accelerated rate, by conditions which affect the bacterial action, and by the action of worms. This unloading of a sprinkling filter, which was at first thought to be a serious objection, is now believed to be its most important advantage, as it prolongs the life of the bed. There are coarse-grain sprinkling filters now in use which have been running 7 or 8 years, and are apparently in good condition. How much longer these filters can be operated will be noted with interest by engineers. It would be a mistake to suppose that they will last indefinitely, but if the material is properly chosen and the sewage is applied at the optimum rate, there seems to be no reason why they may not run from 10 to 15 years before they are renewed.

The rate at which sewage can be applied to sprinkling filters varies according to the character of the sewage, the depth of the filter, the size of the grains, etc. Deep filters can operate at higher rates than shallow filters, and are generally to be preferred. Filters less than 5 ft. deep do not operate satisfactorily, as the time required for the sewage to flow through them is too short. On the other hand, filters deeper than about 12 ft. may involve difficulties in ventilation and in matters of engineering. Depths of from 7 to 8 ft. are generally preferred. Experiment has shown that between 5 and 12 ft., the quantity of sewage which can be applied in a unit of time, varies approximately with the depth, that is to say, a 10-ft.

Mr. Whipple. filter can take twice as much sewage as a 5-ft. filter. The rate which will give the most efficient purification varies inversely as the strength of the sewage. It has been found that for any depth of a sprinkling filter there is a more or less definite quantity of organic matter which must not be exceeded in a unit of time to give the best results; in other words, the size of a sprinkling filter is governed fully as much by the number of people contributing sewage to it as by the number of gallons of sewage applied. The rules of the Local Government Board prescribe a limiting rate of 325 000 gal. daily per acre for each foot of depth when the effluent is to receive further treatment, and 162 500 gal. per acre daily when the effluent is to be discharged directly to the river. Considered on the basis of domestic sewage, this would be equivalent, respectively, to an application of 30 and 15 grams per sq. m. daily, of total nitrogen. Experiments, made at Columbus, Ohio, Lawrence, Mass., and elsewhere, appear to indicate that, in order to obtain effluents which are well nitrified and are not putrescible, the amount of nitrogen applied should not exceed 25 grams per cu. m. daily, or, in other words, that each acre of a sprinkling filter should not receive sewage from more than about 2 000 people for each foot of depth. Carbonaceous matter must be considered, however, as well as nitrogenous matter, and there is an opportunity for further study in connection with this subject.

If sprinkling filters are operated properly they will yield an effluent which is non-putrescible and well nitrified. If coarse grains have been used it will contain more or less suspended matter, for the reasons above mentioned, but this suspended matter will be very different in character from that present in the raw sewage. The purification effected by sprinkling filters seems to be generally better than that obtained by contact beds.

The chief advantages of sprinkling filters are: the purification is good, the effluents are well nitrified and non-putrescible, the filters do not become clogged except at very long intervals, and the rate of application of the sewage is considerably greater than can be obtained by any other process, thereby reducing the area required. Certain disadvantages are: the nuisance occasionally produced by spraying septic-tank effluents, and the difficulty of applying the sewage properly during cold weather. The odor nuisance may be avoided to a practical extent, however, by reducing the degree of septicity of the sewage, that is by spraying stale sewage instead of septic sewage. Experiments at Columbus, Ohio, indicated that sprinkling filters with permanent jets can be operated successfully during cold weather, but this has not yet been tested on a large scale. The idea has been suggested that in case sprinkling filters fail during the winter months they may be arranged so as to be

operated as contact beds during cold weather. The climate of England is mild, even during winter, and therefore this is a problem which it has not been necessary to solve in that country. In the Southern States there would be no difficulty at all in using sprinkling filters at all seasons, and even in the North there is reason to believe that ways and means will be found for operating them successfully. Mr. Whipple.

*Results Obtained by Purification Processes.*—The success of intermittent filtration and broad irrigation in purifying sewage, where suitable conditions for their application exist, has been demonstrated by many years of experience. The practical application of contact beds and sprinkling filters covers a much shorter period, yet it has been long enough to demonstrate that these newer processes may be successfully depended upon if the plants are properly designed and carefully operated. The degree of purification obtained varies greatly under different conditions. Sprinkling filters generally give somewhat higher percentage efficiencies than contact beds.

The new processes of sewage purification are sometimes spoken of as "intensified bacterial processes." That this term is well justified, in so far as it relates to the size of the works, seems evident from the figures of Table 1, which show, in a very approximate manner, the relative sizes of the plants required by the four important methods of purification.

TABLE 1.—APPROXIMATE DATA AS TO SIZES OF PURIFICATION PLANTS.

| | Nitrogen, in grams per square meter daily. | Rate of filtration, in gallons per acre daily. | Population per acre. | Number of acres required per 1 000 people. |
|---|---|---|---|---|
| Broad irrigation..... | 1 | 3 000 to 15 000 | 300 | 3.3 |
| Intermittent filtration..... | 2.5 | 30 000 to 100 000 | 700 | 1.4 |
| Contact beds, 5 ft. deep..... | 20 | 300 000 to 800 000 | 5 000 | 0.2 |
| Sprinkling filters, 10 ft. deep.. | 75 | 1 000 000 to 2 500 000 | 20 000 | 0.05 |

It will be seen from these figures that more than twenty times as much domestic sewage per unit of area can be treated by sprinkling filters as by the method of intermittent filtration. The results with the new processes, to be sure, are not quite as satisfactory, but the effluents are stable and fit to be discharged into streams not used for purposes of water supply. The figures in Table 1, showing the approximate sizes of plants, are not to be taken as applicable to any particular case, especially when manu-

Mr. Whipple. facturing wastes are included. Each local problem must be studied by itself. In some instances the number of acres required may be double the figures given; often the area may be considerably less. The rate of sprinkling filters depends largely upon the size of grain used. In some recent American designs, much higher rates than those given in Table 1 have been recommended.

### Finishing Processes.

The effluents obtained from sub-surface irrigation, broad irrigation, and intermittent filtration methods require no further treatment if the plants are properly designed and carefully operated. They are usually clear enough for all practical purposes, are non-putrescible, and reasonably satisfactory from the bacterial standpoint. This, however, is not true of effluents from contact beds or sprinkling filters. Contact effluents, as well as those from fine-grain sprinkling filters, may be clear and even non-putrescible, but, bacteriologically, they are not good enough to be turned into streams which are used for public water supply purposes, or into tidal estuaries where there is danger that oysters may be contaminated. The effluents of coarse-grain sprinkling filters are not clear, but contain large quantities of suspended matter, as already pointed out.

*Clarification.*—A finishing process, therefore, is necessary when coarse-grain sprinkling filters are used. As the suspended matter in these effluents is comparatively coarse and heavy, it settles readily, and may be removed by the use of shallow settling basins with a short period of sedimentation, or by rough filtration through coarse material, or both. A popular method in England at the present time is to allow the sprinkler effluent to pass through a shallow settling basin, which has a narrow strip of coarse filtering material placed along the side near the outlet. The liquid is made to pass upward through this roughing filter before it is discharged. These settling basins and filters have to be cleaned at rather frequent intervals, a fact which has to be taken into account in calculating operating expenses. The sludge, however, is practically inoffensive, and may be more easily handled than that from the settling tanks used for raw sewage. In some instances the effluent from sprinkling filters is applied to land in order to clarify it, but this has usually been done in order to take advantage of land already owned. No new works are being constructed which involve this feature.

*Bacterial Improvement.*—Experiments made at the London works and elsewhere have shown that, from the standpoint of contamination, the effluent from sprinkling filters or from contact beds is better than that of the raw sewage, but that, while the

organic matter is eliminated from the sewage to such an extent that the liquid is non-putrescible, yet the intestinal bacteria, and presumably the pathogenic bacteria in case the sewage is infected, are not all eliminated by any means, though somewhat reduced in number. It is not safe, therefore, to turn the effluent from a contact bed or sprinkling filter into a stream which is to be used for drinking purposes at some point below the point of discharge, without further treatment. The danger of the contamination of oysters from sewage is now well recognized, and this will have an important bearing on the character of sewage effluents in many places. Mr. Whipple.

In certain cases, therefore, supplementary processes are necessary in order to eliminate the danger of infection from sewage effluents. These may consist of disinfection, or of some one of the methods used for purifying water. Broad irrigation or intermittent filtration might be used; mechanical filtration has also been suggested. Certain disinfectants, such as copper sulphate, chloride of lime, etc., have been studied experimentally, but as far as the speaker is informed, they have not been practically used. This subject, of supplementary treatment in order to minimize the danger from infection by sewage effluents, has not yet been as carefully studied as it seems likely to be in the near future.

## Sludge Disposal.

The disposal of sludge is the most difficult matter in connection with sewage works, and here progress has not been as rapid during the last few years as in connection with the treatment of liquid sewage. Managers and engineers all admit that the sludge problem is still "the problem" of sewage disposal; nevertheless, some advance has been made of late. The change from chemical precipitation to the use of septic tanks has very materially decreased the quantity of sludge to be handled, and, moreover, it has changed the character of the sludge so that it need not now create as much nuisance as formerly.

There are three principal methods of sludge disposal:

1.—Dumping at sea,
2.—Application to land, and
3.—Pressing into cakes.

Carrying the sludge to sea and there dumping it, is the most efficient means of getting rid of it. It is the most expensive, however, and is not practicable except in a few cities favorably situated.

Application to land, if it can be carried on in the immediate vicinity of the sewage works, is the cheapest method, but it is

Mr. Whipple. likely to create more or less nuisance. Mr. Watson's experience at Birmingham, already referred to, is very interesting. He found that, while ordinary sludge from settling tanks cannot be spread upon land without creating offensive odors, sludge which has passed through the process of digestion in the septic tank is inoffensive when disposed of in this way. Such sludge, in one instance, was spread upon a 5-acre field to the depth of 1.5 ft., and gradually dried and settled until it consisted of a layer of what looked like ordinary top soil about 6 in. thick. It was thought at first that crops could be grown on the dried sludge, but this did not prove to be practicable unless earth was mixed with it.

Sludge cannot be easily pressed without the addition of lime, and septic sludge is more difficult to press than either the sludge from chemical precipitation tanks or from plain settling tanks. It requires more lime and more care in operation. Nevertheless, in some places it is done with apparent success.

The value of pressed sludge seldom equals the cost of the lime and the pressing. In some places, where the pressed cake is used for manurial purposes, the sums received from the farmers just about pay the operating expenses, while in other cases the process is carried on at slight loss.

Pressed cake appears to have just about the same manurial value as an equal weight of barnyard manure. It has been found, however, that it does not give good results as a fertilizer when applied continuously year after year to the same piece of land. That is one reason why its sale usually drops off a few years after the sewage plant has been established.

Some sewage sludges are so rich in fats that it is practicable to use them for fuel, or even to recover the grease. The recovery of the grease does not interfere with the later use of the sludge as a fertilizer, as the nitrogen is not extracted. The sludge from settling basins receiving the effluent of sprinkling filters is much less offensive than ordinary sludge. It can be applied to land with practically no nuisance.

At Birmingham, England, where the sludge appears to be well handled, for an inland city, it is said that the general level of the land in the vicinity of the settling tanks is being raised at the rate of about 1 in. a year.

### Disposal of the Purified Effluent.

The object of purifying sewage is chiefly to prevent it from being a nuisance to sight or smell when discharged into some body of water. In certain instances it is further demanded that the effluent shall be satisfactory from a sanitary point of view, in order to avoid the danger of contaminating water supplies or oyster beds.

The subject of sewage disposal by dilution and the effect of sewage effluents on the quality of the water in streams and tidal estuaries is so broad that it cannot be brought within the scope of this discussion, and it is listed merely that it shall not be lost sight of in a general discussion of the subject. Mr. Whipple.

## Disposal of Storm Water.

As so many English cities are sewered by the combined system, the disposal of storm water is an important part of any system of disposal. The rules of the Local Government Board of England require that sewage works shall be large enough to treat twice the dry-weather flow, in the case of separate systems, and three times the dry-weather flow, in case of combined systems, at the rates mentioned previously. A further treatment of storm water is required, up to 4 volumes of dry-weather flow, in the case of separate systems, or 3 volumes, in the case of combined systems. The prescribed minimum rate of treatment on storm beds is 2 900 000 gal. per acre daily. In both cases, therefore, storm flows must be treated in one way or another up to a volume of 6 times the dry-weather flow. Any excess above this may be discharged directly into a stream without treatment.

Storm water is very commonly treated on beds of coarse material operated continuously as long as the storms last, but having long periods of rest between. In order to keep the beds in good condition, however, they are often allowed to receive sewage in small quantities during the dry periods, but care has to be taken that they are not clogged when needed for full duty. During times of storm the period of sedimentation is much reduced, so that suspended matter is often carried to the storm beds in rather large quantities. This, together with the grease which is often present in large quantities, may give rise to surface clogging. Storm beds, therefore, require to be scraped at frequent intervals, or to have the upper layer of material removed and washed.

Instead of using coarse-grain beds, storm water is sometimes turned upon land. It is often the case, when contact beds or sprinkling filters have replaced the older process of land treatment, that the old areas are reserved for the treatment of storm water.

E. Kuichling, M. Am. Soc. C. E.—The excellent presentation of the subject of sewage treatment which has been given by Mr. Whipple is a valuable addition to our stock of knowledge, as it comes from one who has devoted much time to the study of the problem, and whose previous work in chemical and biological fields makes him unusually well qualified to observe and criticize the results attained in this respect in England. The scope of the discussion, however, is so extensive that his paper has left room for Mr. Kuichling.

Mr. Kuichling. some additional remarks, which are offered in the hope of eliciting opinions that may be of service to those who are engaged in planning or operating sewage disposal works.

In most of the papers and reports relating to the treatment of sewage, reference is made to the varying composition or character of the liquid, and to the effect of adding trade wastes to those derived from households. In general, such addition is regarded as rendering the task of purifying the liquid more difficult or expensive, especially when the percentage of trade waste is large. In growing cities the nature of the manufactures often changes, especially in the smaller towns; hence it becomes desirable to devise a plant in which the process of treatment can be varied or modified from time to time, in accordance with changes in the character of the sewage delivered.

The difficulties of treatment increase when the trade wastes contain considerable quantities of fat, soap, dyestuffs, poisonous metallic salts, free inorganic acids, refuse from abattoirs, tanneries, breweries, gas-works, textile mills, etc. On the other hand, a moderate quantity of salts of iron in solution, but containing no free acids, is often regarded as a beneficial addition to domestic sewage, since such salts act as a chemical precipitant of some of the organic matter, and tend to deodorize the liquid. In biological purification, however, it seems to be a matter of much importance that all the iron shall be precipitated in suitable tanks before the liquid is applied to contact beds or filters, otherwise the durability and efficiency of the latter is greatly impaired.

From these considerations it follows generally that the greater the quantity of trade waste, the more complicated must be the plant and the process of treatment, hence the recent tendency of subjecting the sewage to a preliminary chemical precipitation before applying it to contact beds or filters for final purification.

Furthermore, in all operations connected with sewage disposal works, the avoidance or prevention of the formation and dissemination of offensive effluvia must constantly be kept in mind. This feature is, perhaps, the most perplexing and troublesome of all the problems encountered in sewage treatment, as the development of odors from decomposing organic matter obviously varies with the temperature and humidity of the air, while their distribution depends on the wind. It is often stated that fresh sewage has very little odor. This may be true for a short time after its production, but it is a matter of common knowledge that the air contained in municipal sewers is always unpleasant and often becomes highly offensive. The fact is that by the comminution of the decomposing matter in passing rapidly through the waste pipe from the point of production in the building to the street sewer, a vastly greater

emanating surface is formed, and also that the process of decomposition or putrefaction is not arrested by submerging the matter in water. Mr. Kuichling.

It follows, therefore, that the longer the matter remains in the sewer, the stronger will be the odor of the sewage, unless the liquid receives, on its way, an addition of trade waste which tends to destroy the offensive gases or effluvia, as in the case of Leeds, where these wastes contain a large percentage of salts of iron. For this reason also sewage, which has to travel through a long conduit, usually arrives at the disposal works in a more odorous condition than while it was in the tributary sewers. In cool weather the development of effluvium is reduced, and may become slight in winter, but it rarely happens that the odor disappears entirely; hence it becomes expedient to locate the disposal plant as far as possible from habitations. Another reason for such location is the fact that sewage works attract multitudes of flies and other insects, which sometimes become sources of serious annoyance to persons residing in the immediate vicinity.

Even in the rare cases where the sewage arrives at the plant without much offensive odor, trouble will frequently be caused by emanations from the tanks and beds in which the process of purification is carried on, especially when these are of large extent. The appreciation of an odor depends largely upon the magnitude of the emanating surface, so that the effluvium arising from an area of a few square rods may be insignificant, while that which comes from an area of 10 or 20 acres may become intolerable. In the latter case either the plant must be removed, or the adjoining lands must be bought and made part of the works, or else the tanks and beds must be covered, and the effluvia carried by chimneys far enough above the surface of the ground to avoid nuisance. This latter process is usually very expensive, and has not yet been undertaken in extensive works.

As stated by Mr. Whipple, the coarse suspended matter in sewage is always removed by mechanical means in order to reduce the quantity of sludge as much as possible. Various devices have been tried, but the simple inclined grating with bars about 1 in. apart is commonly used in the larger English plants. Few data concerning the quantity of material thus extracted are available, and the only record that the speaker has now at hand is that relating to the screens at Charlottenburg, where, in 1902, approximately 1 cu. m. of solid matter was obtained, on the average, from every 13 250 cu. m. (3 500 000 U. S. gal.) of sewage. There is also a tendency toward obtaining a higher efficiency of the detritus tanks in which sand, pebbles, cinders and other heavy mineral matter settle before the sewage reaches the large sedimentation tanks. At Manchester,

Mr. Kuichling. from a dry-weather flow of about 29 000 000 U. S. gal. per day, the screens and detritus tanks yield about 90 tons of matter per week; but in times of heavy rain they have yielded as much as 140 tons in a single day.

Most of the recent investigations of the subject in England and Germany have led to the conclusion that from two-thirds to four-fifths of the putrescible organic matter, which is carried in suspension in the sewage, can be removed by simple sedimentation, and that, in many cases, the effluent from such tanks may be safely discharged without further treatment into relatively small rivers, when the same are not used for water-supply purposes. This opinion was also entertained years ago, after some experience had been gained with sedimentation alone, but it was crowded aside by the promoters of various chemical processes, as well as by those who sought for still better results by other means. It is, therefore, interesting to note the revival of some former doctrines and the confirmation of their soundness by the newest methods of research.

Associated with the efficiency of simple sedimentation is the old project of attaining the same end mechanically by screening the sewage through a sieve having very small meshes. Many experiments in this direction were made in former times, but were abandoned because an entirely clear effluent could not be produced thereby. The demonstration of the fact that, in many cases, clearness and sterility of effluent are not essential features of sewage treatment, will probably also lead to the trial of other screening devices in the hope of avoiding the great expense of existing processes.

Where chemicals are used for precipitating the suspended matter, the quantity ranges in general from 2.8 to 9.4 gr. per U. S. gal., or from 400 to 1 340 lb. per million gallons. Lime is used at rates ranging from 2 to 5 gr. per gal.; sulphate of iron or copperas at from 0.82 to 4.67, and alum or compounds of iron and aluminum sulphate at from 1.29 to 7.01. The quantity used varies with the character and strength of the sewage in each case, and also with the nature of the trade waste; and in most cases a variation in the rate of admixture is made at different hours of each day.

No settled practice seems to have been established in regard to the form and size of the sedimentary and finishing tanks and the total storage volume to be provided. In 1903 the requirements of the Local Government Board were that the works should be capable of purifying, in a satisfactory manner, at least six times the daily dry-weather flow, and that three times this flow should be purified in the same manner as when no rainfall occurs. When the discharge is three times the dry-weather flow, the tanks of a double-treatment system may be emptied twice and filled three times in

the course of 24 hr., so that the storage capacity shall be equal to the daily dry-weather flow. In addition to this standard capacity, one or more storage units must be held in reserve for use in case of repairs to some of the others. Where the purification is done in only one set of tanks, the storage capacity should be equal to 1.5 times the dry-weather flow. It may be remarked, however, that these requirements are not usually fulfilled, and that, in the majority of cases, the storage capacity is not more than one-half the daily dry-weather flow. Mr. Kuichling.

The most important result of the recent investigations, however, is that the new methods of treatment have not succeeded in eliminating the production of sewage sludge. While it is true that an appreciable reduction of the quantity of sludge is effected by the septic process, yet enough of this objectionable matter remains to cause serious embarrassment and expense in large plants. As far as can now be foreseen, it will be necessary to remove such matter periodically from both sedimenting and septic tanks, as well as from contact beds and filters. The frequency of these operations obviously depends on the character of the sewage and the trade wastes, and the data are not yet sufficient to admit of the formulation of reliable estimates in this respect. It may be said, therefore, that the new processes have been somewhat disappointing, and that there is still room for much improvement.

George W. Rafter, M. Am. Soc. C. E. (by letter).—In view of the discussion before the International Engineering Congress, at St. Louis, in 1904, this topic might be more properly stated as, "Has there been any advance in sewage disposal," and does it mean advance in sewage disposal in the United States, or in England, or the whole world, or where? As far as the writer is concerned, the topic will be discussed chiefly from the point of view of advance in sewage disposal in the United States in the last few years. Mr. Rafter.

Engineers must go to England for the bulk of the information about sewage disposal, although fifteen years ago, the State Board of Health of Massachusetts, with its classical experiments on intermittent filtration, for a time led in this specialty. Later, the palm went to England, and has since remained there, the most of the work done here in recent years being largely on the lines laid down by the English experimenters, so that, to-day, if one wants the present practice, he must go to the report of the Royal Commission on Sewage Disposal, where, with an unparalleled wealth of detail, nearly every phase of the subject has been considered. For the last few years, American investigators have allowed the palm to remain in England, but it is hoped that in any further work undertaken here, new lines may be worked out so as to reverse this, to some extent.

Mr. Rafter. While the foregoing is somewhat sweeping, nevertheless there are indivdual examples of creditable advance in sewage disposal work in America, but the statement is made that, as regards the broad lines, the advance in England in the last few years has been much more rapid and on more material points than in the United States. The writer will not discuss the relative points, because they ought to be obvious to any person familiar with sewage disposal.

Mr. Johnson. WILLIAM S. JOHNSON, ASSOC. M. AM. SOC. C. E.—Mr. Whipple has given a remarkably clear and interesting account of the present status of the sewage disposal problem in England, but the speaker regrets that he has confined himself to the practice there, where conditions are so divergent from those which obtain in the ordinary American city that, in many respects, the problem is entirely different. He states that one must go to England to find the latest developments in the art of sewage purification. It is undoubtedly true that the latest developments are found there, but the speaker believes that in America the highest development exemplified in intermittent filtration may be found. The great interest in recent English experiments has, to some extent, obscured this system which has been developed in America to meet American conditions, and which has proved successful in so many places.

In a recent editorial in one of the leading engineering papers the following statements were made:

"The rise of intermittent filtration has reached its culmination. It is now known that it is much more expensive than was formerly anticipated, and the character of the effluent which it furnishes is often unnecessarily good for discharge into the body of water receiving the purified sewage. One by one the intermittent filters constructed in New England, a number of years ago, are becoming clogged and inoperative, except at very low rates, and the heavy initial expense, which is usually necessary for such filters, is recognized as merely a forerunner of heavy maintenance charges."

These statements, to one familiar with the New England intermittent filtration works, are amazing. The intermittent filtration areas in Massachusetts, almost without exception, purify the sewage satisfactorily during nine or ten months of the year. The purification is practically as satisfactory in cold weather as in warm, until the accumulation of solid matter on the beds, during the time when the surfaces cannot be cleaned on account of ice, becomes so great as to cause clogging. Not one of the plants is becoming inoperative, although several have been outgrown, and the sewage discharged upon them during the spring months is more than they can purify satisfactorily.

The only serious difficulty which is experienced in the opera-

tion of the plants is that due to the clogging of the beds in the late winter and spring, after the surfaces have been inaccessible for several months. At such times, not only are the surfaces of the beds clogged by the accumulated solid matter, but the flow of sewage is at its maximum. To purify the sewage at such times, with plants as now constructed, it is necessary to provide an area at least twice as great as that which would be required during the remainder of the year. During the time when this trouble is experienced, the flow of the streams is high, and the discharge of unpurified sewage directly into them is likely to cause little offence. In Massachusetts, however, the State Board of Health objects to the discharge of unpurified sewage from a purification plant at any time, insisting that the plant shall be of sufficient capacity to meet the greatest demands. It is this high standard adopted by the Massachusetts State Board of Health which is probably responsible for the opinion in regard to intermittent filtration given in the editorial quoted. Mr. Johnson.

The satisfactory results from intermittent filters are obtained in spite of the fact that many of them are badly neglected. This, it seems to the speaker, is one of the great advantages of the system. The plants, if well designed in the beginning, give results which are much more satisfactory than those obtained by the more rapid systems, even though neglected, as they are sure to be in many cases, especially in the smaller cities and towns, while the rapid systems require constant and intelligent care.

The intermittent filtration areas of New England are purifying the sewage of from 500 to 2 000 persons per acre—a much greater quantity than was anticipated. With improvements in construction and with the adoption of suitable works for the removal of a portion of the solid matter, it is probable that the ordinary sewage of from 1 500 to 2 000 persons can be disposed of satisfactorily on each acre of filter beds.

The cost of maintenance of intermittent filtration areas depends, to a considerable extent, upon their size, but, for the larger works, it is from 10 to 15 cents per year per person contributing sewage, and, with increased knowledge in regard to the maintenance of the beds, this figure is being decreased.

Failure to realize the difference in conditions in different places has resulted in a mistaken idea as to the quantity of sewage which can be treated by the various systems of purification. The figures usually given for intermittent filtration are for fresh sewage from which none of the solid matter has been removed. The figures given for the capacity of trickling and contact filters, on the other hand, are generally those for septic sewage or at least for sewage from which a large proportion of the solid matter has been removed. In

Mr. Johnson. the experiments recently made at Columbus, Ohio, it was shown that the quantity of sewage which could be purified by intermittent filtration was about one-eighth of that which could be purified by trickling filters, similar sewages being used in each case. In the few intermittent filtration works in New England where there is a thorough preliminary treatment of the sewage, quantities of sewage amounting to 250 000 gal. per day are purified by an acre of sand filter beds. Furthermore, in comparing the work which can be done by the various systems, it must be remembered that it is essential in the case of trickling filters to construct works for the further purification, or at least clarification, of the effluent to make it at all comparable with the effluent even from an overworked and badly managed intermittent filter. Experience in the operation of the two classes of filters tends to show that larger quantities than were anticipated can be purified by intermittent filtration and smaller quantities by trickling filters. When the cost of maintenance and the cost of renewals of the filtering material are taken into consideration, it will be found that intermittent filters can frequently compete with the so-called rapid filters, even when it is necessary to convey the filtering material for these filters from a considerable distance, and the results obtained by intermittent filtration are sure to be much more satisfactory.

In this discussion the speaker simply wants to emphasize the fact that developments in the art of sewage disposal in England do not necessarily apply to American conditions, and that the most recent development may not be the highest. Intermittent filtration is not a stage in the development of sewage purification which has been passed or which is even passing, but it represents to-day the highest development of the art of sewage purification under American conditions.

Mr. Maignen. J. P. A. MAIGNEN, ASSOC. AM. SOC. C. E.—The subject of sewage disposal is quite extensive, and the speaker will simply draw attention to a few points for further consideration, presenting these points in the form of questions.

The first question is: Is it desirable to screen the sewage that goes into the septic tank?

If the so-called septic action consists in the decomposition of dead organic matter by bacteria and in its reduction to inorganic substances, it would appear as if the more food allowed to go into the septic tank, the more strenuous and complete would be the septic action.

It is well known that all portions of what has once been a living body, vegetable or animal, which have been cut off the trunk or deprived of life, as well as all animal excretions, commonly called organic matter, are destined, whether they be in water, in sewage,

Mr. Maignen.

or in any other moist environment, to be decomposed by certain kinds of bacteria, which, unless fed by new material, die after having done their work.

Place a bottle, or other vessel, full of fresh sewage, upon a table or shelf, and examine the bacterial process. One may find on the first day, for instance, 500 000 bacteria per cu. cm., the second day, 1 000 000, and the third day, 2 000 000. The number may go on increasing for a certain number of days; then comes the time when the increase ceases, and, on the contrary, the bacteria begin to die out; so that, supposing the number to have been, say, 4 000 000 on the fourth day, it may, by the tenth day, have fallen to 2 000 000, on the fifteenth to 1 000 000, on the twentieth to 500 000, and on the thirtieth day the number may be reduced as low as 50 000.

The offensive odor, which rises from sewage in a state of decomposition, indicates the presence and work of the bacteria.

When crude sewage is emptied into rivers, the decomposition is distributed over a large area, and the quantity of gas produced in any one place is hardly noticeable. But, under these conditions, it may be easily understood that infection can be carried a long distance. By infection is meant the entrance, into the human system, of bacteria which have been living on dead, or diseased, animal or organic matter.

Water, taken in barrels by ships from rivers known to be polluted, such as the Delaware River, becomes foul after a few days at sea, but later it becomes sweet and pure. By this time, all fermentation or putrefaction has ceased. The same thing occurs in rain-water tanks, in cider-making, and in wine-making. As long as there is appropriate food, the bacteria thrive and go on increasing until, in the last act, they all die, as in Shakespeare's plays.

The question, then, may be asked: Why should not all the material that comes from the sewage enter the septic tank? Why should any part of the food which is to help the septic action be taken out by screening?

The next question is: What manurial value, if any, is there in fresh sewage, or in the sludge or scum of septic tanks?

A few weeks ago, Dr. Samuel G. Dixon, Health Commissioner of Pennsylvania, in drawing public attention to the danger of infection from sewage, laid particular stress on its fertilizing value, which is wasted under present conditions. It is in order, therefore, to ask whether it would not be possible to do with the sewage of towns what is being done with farm refuse? Does the septic action destroy all manurial value, or does it leave some, and if so, how much? And would it not be desirable to study, more thoroughly than has hitherto been done, the utilization of fresh sewage?

The speaker is aware that this is not a new question. Thus, for

Mr. Maignen. instance, sulphate of ammonia is extracted from the product of odorless excavations in Paris, and fresh sewage is thrown on farm lands in many places, but it occurs to him that there are not enough data in the United States on the whole question of the manurial value of fresh sewage, or of the residue of septic tanks.

In Paris new fields are being constantly added for the filtration of sewage by what is known as broad irrigation, but these have not kept pace with the requirements. The rivers are more polluted than ever with the overflowing raw sewage from the sewage farms. The reason is that the fatty and greasy substances do not decompose but turn the sand or soil into a kind of putty, which prevents filtration, so that the ground ceases to absorb liquids in the desired quantity.

Of course in times of rain and frost much of the raw sewage goes directly into the rivers. It is appropriate, therefore, to ask for a thorough investigation of the question of utilizing the manurial properties of sewage, both as to what has been done, and as to what ought to be done.

As a general rule, chemicals, such as iron or copper, are inimical to vegetation, but this may not be the case with lime, which has been used extensively in sewage purification. It may be that, in those countries in which the soil is poor in lime, and where lime is actually spread on the fields to enrich the soil, the use of this earthy salt, for sewage purification, would be desirable. Lime, impregnated with partly decomposed organic matter, may have acquired some additional manurial property which would pay for the trouble of utilizing it in sewage purification. Any information on this subject might prove of interest.

The speaker would like to ask Mr. Whipple as to the cost of sewage treatment in England per million gallons by the various processes which he has described.

A thought now occurs to the speaker, which perhaps might better have been mentioned earlier in the discussion, but which is of sufficient interest to be submitted for consideration.

It has been seen that sewage and water, which contain organic matter, pass through a stage of fermentation, attended, in some cases, with the production of gas; and that after a time such sewage or water becomes odorless and innocuous; in other words, that the multiplication of bacteria is not without limit in time, space, or number. Take, for instance, a gelatine plate on which a bacterial culture is made. At first mere points or dots are seen, which are called colonies; some of these points remain small, while others grow larger and attain different dimensions, varying from $\frac{1}{16}$ to $\frac{1}{4}$ in. in diameter, and then they stop. The bacteriologists might perhaps tell us why there is this limit in growth, and why a single colony does not grow so as to cover the whole plate?

There are some liquefying bacteria which, if allowed, would decompose the whole gelatine, but there are others which remain within specific limits. Mr. Maignen.

It is supposed that the product of bacterial metabolism is poisonous to its own kind, as would be the case if too many persons were confined in a closed room where the carbonic acid exhaled would poison the people so confined. The same phenomenon probably obtains in the case of sewage, and perhaps this may be accounted as one of the causes of so-called self-purification.

In conclusion, the speaker would like to ask Mr. Whipple whether, on his last visit to Paris, he took a ride in a boat in the sewers? This used to be one of the sights of Paris, as much as the Tour Eiffel. These sewers are large enough to pass the flow of sewage and also to furnish room for water-pipes, gas-pipes, etc. When the speaker was in Paris, he understood that these sewers took only the surface water, and he would like to know whether house sewage is now allowed to mix with it?

CLYDE POTTS, ASSOC. M. AM. SOC. C. E. (by letter.)—Mr. Whipple's paper is an exceedingly interesting discussion of the sewage disposal plants studied by him while abroad, and, as such, is a valuable addition to the ever-increasing literature on sewage disposal. Mr. Potts.

While the paper treats of English methods and their application to American cities, it does not treat of American practice, or rather of what American conditions are bringing about in contradistinction to what English conditions have evolved in England.

It is apparent to all that each municipality having a live question of sewage disposal must study its own particular needs. This study involves the concentration of the sewage, the time required to reach the disposal plant, the degree of purification consistent or desired, the quantity of manufacturing wastes, the filtering material locally available, and the financial standing of the municipality. In short, it is a complete case of individual study, just as each case that comes to a physician is an individual study.

In England the symptoms are different, and the available remedies are also different. Americans are lavish users of water, and their sewage is much more highly diluted than English sewage. In speaking of disposal plants, if one could use the terms, persons per acre or square feet per person, for filter beds, and, cubic feet per person, for sedimentation tanks, the data from different communities and cities would be more comparable, as reference to water consumption per capita would be avoided. In America, filtration is the distinctly American practice, and sewage purification could well be called "the filtration of highly polluted water," or "the filtration of dilute sewage." The term "purification of public water supplies"

Mr. Potts. seems to be a misnomer. As all surface waters are more or less polluted, it is generally conceded that all need some treatment before use. In treating these waters it is true that purification is attempted, but is it ever achieved? The time is not far distant when the field of the so-called specialist in the filtration of public water supplies (polluted water), and the specialist in sewage disposal (the filtration of highly polluted water), will be one and the same. Sewage is water, and though it be highly polluted with human excreta and waste, it is water, nevertheless, and carries a certain definite quantity of organic matter per 80 gal., per 100 gal., or perhaps per 300 gal., according to what the per capita consumption of water may be.

The great number of American sewage disposal plants that have been built, and the tendency of the times seem to indicate that filtration through sand beds, natural or artificial, is the principal and ultimate step in the attempted purification of sewage. It is Nature's own method, and if the life of the sand beds can be saved and the cost of maintenance cheapened by introducing sedimentation tanks, contact beds, coarse primary filters, scrubbing filters, sprinkling filters, etc., the final and principal step will still be filtration. The only thing achieved by these preliminary steps is the reduction of the number of square feet of filters required for each person contributing organic matter to the sewage. For each individual case in sewage disposal there is an economic limit to the size of filters, as determined by the cost of the preliminary steps leading to filtration. In some localities where preliminary steps will give a non-putrescible effluent, it is not worth the added cost to build filters; but the time is not far distant when the needs of society will compel, in all cases, the highest degree of purification possible.

Mr. Pratt. R. WINTHROP PRATT, ESQ.* (by letter).—Mansfield, Ohio, has a population of approximately 20 000, about one-half of which is tributary to the city sewers. The system consists of 25 miles of sewers, about 60% of which are on the combined plan, and 40% are used for domestic sewage only. Automatic overflows divert a portion of the sewage directly into the creek at times of storm.

The sewage is rather dilute most of the time, due in part to leakage into the old combined sewers; and there are no manufacturing wastes to complicate its composition. The average daily quantity of sewage treated at the disposal works is about 1 000 000 gal.

The disposal plant consists of covered septic tanks and contact beds. There are four tanks, each 50 by 100 ft., with an average depth of 8 ft. This gives a total tank capacity of 1 000 000 gal., or about 24 hours' flow. An automatic floating weir secures a con-

* Chief Engineer, Ohio State Board of Health.

stant discharge from the tanks. This causes a daily fluctuation of about 6 in. in the elevation of the surface of the liquid. Mr. Pratt.

There are five contact beds. Each is filled with 5 ft. of specially prepared cinders, and has an area of ¼ acre, making a total area of 1¼ acres.

The sewage enters the septic tank through four 12-in. pipes, 10 ft. apart and 3½ ft. below the surface of the liquid. The sewage is drawn off at the lower end of each tank through 2-in. pipes discharging into a collecting channel, outside of the main wall of the tank, about 2 ft. wide and 3½ ft. deep. The sewage flows from this channel through the floating weir into an 18-in. pipe leading to the aerator, and thence to the contact beds.

### Sludge Disposal.

After 4 years' operation it was found that these outlet pipes had become clogged to such an extent that the sewage could not pass from the tanks. It was decided, therefore, by the local authorities, that cleaning was desirable. The actual deposit of sludge in the tank at the time of cleaning was only 2 ft. at the upper end and 1 ft. at the lower end. The collecting channel contained a deposit 6 or 8 in. deep.

Two theories are presented to explain the clogging of the 2-in. outlet pipes: First, that the increased bacterial action at the bottom of the tank, which takes place in the spring, caused the sludge to rise and be carried into the 2-in. pipes; and second, that the accumulated suspended matter in the outside collecting channel became so great as to cover the outlets of these small pipes and clog them. If this last theory is true, then the cleaning of the septic tanks at this time was not necessary.

The removal of the sludge from one of the tanks was effected by drawing off the supernatant sewage and then opening the sludge valve and flushing the sludge directly into the creek. This flushing was directed by men who entered the tank and aided the work when necessary. It was found that the sludge was of such a pasty consistency that it would not flow readily, but needed considerable dilution.

After cleaning the first tank, the stage of the river decreased to a decided extent, and it was not thought wise to adopt this method with the remaining three tanks. Therefore, a framework with hoisting apparatus was erected in turn over each of the manholes in the other three tanks, and barrels were lowered into each and filled by five men working therein with buckets. It is said that about 250 bbl. of sludge were removed each day by this method. Each barrel, after being hoisted to a height of 10 ft. above the top of the tank, was discharged by tipping into a sluice-way which led

Mr. Pratt. down a steep embankment to a small piece of low, marshy land adjoining the works.

The total quantity of sludge removed was about 1 200 cu. yd. The cleaning of the tanks required 5 or 6 men for 3 weeks. The cost was about 50 cents per cu. yd. Based on an average daily flow of 1 000 000 gal., the accumulation in the tanks, during the 4 years of service, was about 0.8 cu. yd. of wet sludge per million gallons of sewage.

The sludge was of a deep black color, but had no appreciable odor; that is, with the wind blowing directly from the pool of sludge deposited on the low land, adjoining the works, practically no odor was carried more than 100 or 200 ft. on a warm and clear day. Sludge, which had been accidentally spilled around the top of the manholes, turned from black to a dark brown in a few days; and then, when dry, was little more offensive than ordinary garden earth. The change of color was apparently due to the oxidation of the iron sulphide contained in the sludge.

As noted from the following analysis, this is a typical septic sludge, and apparently has been so worked over by bacteria as to render it comparatively inoffensive. The analysis shows the sludge to be very similar in composition to that found in the septic tanks at the Columbus, Ohio, Testing Station after 11 months' operation.*

ANALYSIS OF SLUDGE FROM MANSFIELD SEPTIC TANK.

First Cleaning After 4 Years' Use.

| | |
|---|---|
| Specific Gravity | 1.11 |
| Water | 80.8 |
| Solids | 19.2 |
| Volatile | 3.6 |
| Nitrogen | 1.03 |
| Fats, acid | 4.65 |
| Iron (Fe), total | 0.77 |
| FeS | 0.764 |
| Fe, not as FeS | 0.28 |

The experience at Mansfield is of particular interest in showing that it is possible to operate a septic tank continuously for 4 years without any serious accumulation of sludge; and that the sludge can be discharged into the open air and deposited on ground near the plant without creating offensive conditions. This seems to conform more closely with European experience, as reported in the United States, than anything which has hitherto come under the writer's observation.

Acknowledgment is made to Mr. L. A. Keith, City Engineer of Mansfield, for information relating to the cost of the work.

* "Report on Sewage Purification for Columbus," by George A. Johnson, 1905, p. 131.

# MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

## PER BRYNN, Assoc. M. Am. Soc. C. E.*

DIED FEBRUARY 10TH, 1906.

Per Brynn was born at Modum, Norway, on February 21st, 1866. He received his early education in a private school, at the place of his birth. Later, he attended the high school at Drammen, from which he was graduated with high honors in 1882. He then entered the Technological Institute at Trondhjem, from which he received the degree of M. E. in 1886. The following year was devoted to a post-graduate course in Civil Engineering in the same institution.

In 1887 Mr. Brynn came to America, and entered the service of the Shiffler Bridge Company, of Pittsburg, in the capacity of draftsman and estimator. In January, 1894, he was placed in charge of the Annex to the Company's main drawing room, where he remained until August, 1898, when he was promoted, being put in charge of the branch office in Philadelphia. In June of the following year he was recalled to Pittsburg and appointed Chief Draftsman for the Company.

When the Shiffler Bridge Company was taken over by the American Bridge Company, in May, 1900, Mr. Brynn was placed in charge of one of the structural departments of the latter company, where he remained until the time of his death.

Mr. Brynn was a man who left the impress of his personality on all who met him. One felt immediately that he was worth knowing—an impression that association only strengthened and confirmed. He was always dignified and reserved, unassuming in manners, and thoughtful of others. Sincerity of purpose and faithful effort characterized his whole work and gained for him the high regard of all who knew him.

On February 1st, 1906, Mr. Brynn was married to Mrs. Josephine Opsion, of Pittsburg. Just ten days later, in New York City, while still on their wedding trip, he passed away. He is survived by his wife, his mother and three sisters, who reside at Drammen, Norway, and two brothers, Mr. Anders Brynn, of Christiania, Norway, and Mr. Soeren Brynn, of Pittsburg.

Mr. Brynn was elected an Associate Member of the American Society of Civil Engineers on February 4th, 1903.

* Memoir prepared by James K. Lyons, M. Am. Soc. C. E.

## FREDERICK APPEL HAUSMAN, Jun. Am. Soc. C. E.*

DIED MARCH 6TH, 1906.

Frederick Appel Hausman was born in Allentown, Lehigh County, Pennsylvania, on August 8th, 1880. He was graduated with honorable mention, as civil engineer, from Lehigh University with the Class of 1901. While at Lehigh he was a member of the Tau Beta Pi, an honorary technical society.

During college vacations, that is, between June and September, 1899, he was Rodman for the Lehigh Engineering Company, of Allentown, Pennsylvania, and, from June to September, 1900, he served as Assistant in the Engineering Department of the Atlas Portland Cement Company, of Northampton, Pennsylvania.

After graduation in June, 1901, Mr. Hausman began work as Draftsman in the corps of the Chief Engineer of the Lehigh Valley Railroad at South Bethlehem, Pennsylvania, where he remained until January, 1902, when he accepted a position as Assistant Supervisor with the Philadelphia and Reading Railroad at Bridgeport, Pennsylvania. In this position he had full charge of much important work and handled it in a very able manner. His superiors fully appreciated his services, and very reluctantly accepted his resignation in May, 1903.

At this time, his father, Mr. W. A. Hausman, Sr., called upon him to assume the management of his brickyard at Allentown, Pennsylvania. This business demanded the entire attention of a competent and reliable man. To manage successfully a business of this kind, which operates only during the summer and autumn, requires a knowledge of how to handle men, together with business and engineering abilities. When "burning" it is often necessary for the Manager to remain at the kilns day and night, as the men generally employed in brickyards are not very reliable. In this position, Mr. Hausman acquired a thorough business training.

He remained with his father until November, 1905, when he again accepted a position as Assistant Supervisor, which was offered to him by the Philadelphia and Reading Railroad Company, at Olney, Pennsylvania. He was filling this position with credit when he contracted typhoid fever, and, after a severe illness of five weeks, he died on March 6th, 1906.

During his illness he had been asked to become City Engineer of Allentown, Pennsylvania, but, of course, could not accept it.

Mr. Hausman was a broad and a clear thinker, and a bright engineer. He had a firm sense of duty which would have shown its

* Memoir prepared by C. J. McGonigle, Esq.

effect later. His love for his family and home was carried to excess; in fact, he refused several good positions because they would have taken him too far from home.

Mr. Hausman was elected a Junior of the American Society of Civil Engineers on February 3d, 1903.

# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

OF

# CIVIL ENGINEERS.

(INSTITUTED 1852.)

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VOL. XXXII. No. 7.

SEPTEMBER, 1906.

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NEW YORK 1906.

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# American Society of Civil Engineers.

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*Vice-Presidents.*

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*Treasurer*, JOSEPH M. KNAP.

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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CABLE ADDRESS: "Ceas, New York."

Vol. XXXII. SEPTEMBER, 1906. No. 7.

# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## SOCIETY AFFAIRS.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

**September 5th, 1906.**—The meeting was called to order at 8.30 P. M.; Rudolph Hering, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 96 members and 12 guests.

The minutes of the meetings of June 6th, and of the Annual Convention, June 26th to June 29th, 1906, were approved as printed in the *Proceedings* for August, 1906.

A paper, by Wilbur J. Watson, M. Am. Soc. C. E., entitled "Concerning the Investigation of Overloaded Bridges," was presented by the Secretary, who also read a communication on the subject by R. D. Coombs, Assoc. M. Am. Soc. C. E. The paper was discussed by Messrs. Mansfield Merriman, George H. Pegram, Henry B. Seaman and George B. Francis.

Ballots for membership were canvassed, and the following candidates elected:

As Associate Members.

Philip Lee Bush, San Francisco, Cal.
Richard Sanders Chew, San Francisco, Cal.
Albert Beeston Dodd, Mitchell, Nebr.
James Valence Nimmo, Paspebiac, Que., Canada.
Herbert Anson Warren, New York City.

The Secretary announced:

The transfer of the following candidates by the Board of Direction, on September 4th, 1906:

From Associate Member to Member.

Samuel Pond Baird, Portsmouth, Ohio.
Adrian Benoni Bentzon, Lima, Peru.
Fred Lavis, Hoboken, N. J.
Marshall Pope Robertson, New Orleans, La.
Richard Lord Russell, Brooklyn, N. Y.
George Fetter Stickney, Albany, N. Y.

The election of the following candidates by the Board of Direction:

As Juniors.

On April 3d, 1906:
Elvin Jay Becker, Lenox Dale, Mass.

On June 5th, 1906:
Nathan Newton Tiffany, East Hampton, N. Y.

On September 4th, 1906:

Percival Stevens Baker, Philadelphia, Pa.
James Evans Barlow, Lawrence, Mass.
Wayne Joseph Burton, Pueblo, Colo.
Orville Berton Carlisle, Ambridge, Pa.
Horace Edward Chandler, Scranton, Pa.
Le Roy Walter Clark, Troy, N. Y.
Edgar Stone Closson, Gloversville, N. Y.
Marcus Martin Farley, Trenton, N. J.
Thomas Omar Gilland, Philadelphia, Pa.
Francis Ingraham Greene, Providence, R. I.
Carl Porter Hoff, Columbia, Mo.
Leonard Louis Hohl, Berkeley, Cal.
Edward Wyllys Hyde, Jr., Chicago, Ill.
Orlando William Irwin, Cleveland, Ohio.

CLARENCE SYLVESTER JARVIS, Provo City, Utah.
ARTHUR CASWELL KING, Taunton, Mass.
RICHARD LEE LINDSAY, Atlanta, Ga.
HERBERT DRUMMOND MENDENHALL, Monkey Point, Nicaragua.
CHARLES DOUGLAS MERCER, Providence, R. I.
OSCAR WILLIAM RACKLE, Providence, R. I.
WALTER PERCY SAWYER, Chicago, Ill.
JAMES LOYD THOMPSON, Corbett, Wyo.
CHARLES EDWARDS TIRRELL, South Weymouth, Mass.

The Secretary announced the following deaths:

ROBERT BRUCE BURNS, elected Member, September 5th, 1900; died June 21st, 1906.

CHARLES PAINE, Past-President, Am. Soc. C. E., elected Member, December 4th, 1867; President, January 17th, 1883, to January 16th, 1884; died July 4th, 1906.

GEORGE HENRY ROBINSON, elected Member, March 7th, 1888; died July—1906.

GEORGE Y. WISNER, elected Member, April 5th, 1876; died July 3d, 1906.

MOSES HANNIBAL WRIGHT, elected Junior, January 2d, 1900; Associate Member, September 3d, 1902; died June 8th, 1906.

EDWARD COOPER, elected Fellow, December 10th, 1885; died February 25th, 1905.

**September 19th, 1906.**—The meeting was called to order at 8.35 P. M.; President Frederic P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, 130 members and 16 guests.

A paper by Clifford Richardson, Assoc. Am. Soc. C. E., entitled "Street Traffic in New York City, 1885 and 1904," was presented by the author. A communication on the subject from S. Whinery, M. Am. Soc. C. E., was presented by the Secretary, and the paper was discussed by Messrs. N. P. Lewis, G. W. Tillson and the author.

A paper by Charles S. Churchill, M. Am. Soc. C. E., entitled "The Ventilation of Tunnels," was presented by the Secretary, who also read a communication on the subject by G. S. Rice, M. Am. Soc. C. E. The paper was discussed by Messrs. R. P. Bolton and G. C. Henning.

The Secretary announced the following deaths:

JONES MUMFORD JACKSON, elected Member September 1st, 1886; died September 6th, 1906.

GEORGE TATNALL, elected Member May 3d, 1899; died September 13th, 1906.

Adjourned.

## OF THE BOARD OF DIRECTION.

(Abstract.)

**June 27th, 1906.—10 P. M.**—The Board met, as required by the Constitution, at the Annual Convention at Frontenac, N. Y., President Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Ellis, Gowen, Green, Knap, Kuichling, Schneider, Sherrerd, Smith, Swensson, and Webster.

Charles B. Dudley, M. Am. Soc. C. E., was appointed to represent this Society at the IV. Congress of the International Association for Testing Materials, to be held at Brussels, Belgium, September 3d to 8th, 1906.

Adjourned.

**September 4th, 1906.**—Vice-President Kuichling in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bissell, Bowman, Gowen, Green, Knap, Landreth, Lewis, Moore, Schneider, Sherrerd, and Smith.

The President was authorized to appoint a representative of this Society to attend the dedication exercises of the new building for the engineering departments of the University of Pennsylvania on October 19th, 1906.

The resignation of James A. Wilson, Jun. Am. Soc. C. E., was accepted.

A list of nominees for the offices to be filled at the next annual election was received from the Secretary of the Nominating Committee.

The following Committee was appointed to recommend the award of prizes for the year ending with the month of July, 1906: Messrs. Edward W. Howe, John L. Van Ornum, and Alfred D. Flinn.

Applications were considered, and other routine business transacted.

Six Associate Members were transferred to the grade of Member, and twenty-three candidates were elected as Juniors.*

Adjourned.

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* See page 320.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, October 3d, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper, entitled "The Narragansett Bay Coal Depot," by Augustus Smith, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in *Proceedings* for August, 1906.

**Wednesday, October 17th, 1906.**—8.30 P. M.—At this meeting two papers will be presented for discussion, as follows: "Fountain Flow of Water," by Messrs. F. E. Lawrence and P. L. Braunworth; and "Additional Information on the Durability of Wooden Stave Pipe," by Arthur L. Adams, M. Am. Soc. C. E.

The paper by Messrs. Lawrence and Braunworth was printed in *Proceedings* for August, 1906; Mr. Adams' paper is printed in this number of *Proceedings*.

**Wednesday, November 7th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Works for the Purification of the Water Supply of Washington, D. C.," by Allen Hazen and E. D. Hardy, Members, Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

**Wednesday, November 21st, 1906.**—8.30 P. M.—At this meeting a paper entitled "Steam Locomotive and Electric Operation for Trunk-Line Traffic—A Comparison of Costs and Eearnings," by Joseph Mayer, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

**Wednesday, December 5th, 1906.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "The Atchafalaya River: Some of Its Peculiar Physical Characteristics," by J. A. Ockerson, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

## PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 803 Fulton Building, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner, Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten- Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesbrough, England.

**Civil Engineers' Society of St. Paul,** St. Paul, Minn.

**Koninklijk Instituut van Ingenieurs,** The Hague, The Netherlands.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

## LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

### San Francisco, Cal.

**June 16th, 1006.**—A regular meeting of the San Francisco Association of Members, Am. Soc. C. E., was held; Edwin Duryea, Jr., President, in the chair; Franklin Riffle, Secretary.

Progress reports were received from the special committees on Geology of the Earthquake; Building Construction; Sewers; and Water Supply.

The final report of the Special Committee on Lighting and Transportation was read by the Secretary.

Messrs. J. H. Wallace, H. C. Phillips, R. M. Drake and E. M. Boggs were appointed a special committee to report upon the Effect of the Earthquake on Railroad Structures.

It was decided to appoint a special committee to report on the Effect of the Earthquake on Highway Bridges.

It was decided to invite, to one of the regular meetings, the members of the Local Association of the American Institute of Architects, for the purpose of discussing architectural construction.

**August 18th, 1906.**—A regular meeting of the San Francisco Association of Members, Am. Soc. C. E., was held; Edwin Duryea, Jr., President, in the chair; Franklin Riffle, Secretary; and present, also, 21 members and 6 guests.

Progress reports were received from the special committees on Geology; Building Construction; Water Supply; and Sewers. Final reports were received from the special committees on Highway Structures and Railroad Structures.

# ACCESSIONS TO THE LIBRARY.

From August 6th to September 8th, 1906.

## DONATIONS.*

### FIVE FIGURE LOGARITHMS

Of Numbers and Angular Functions, for the Use of the Engineer, Constructor and Student. By Henry Harrison Suplee. Morocco, 7 x 4 in., 91 pp. Philadelphia, J. B. Lippincott Company, 1906. $2 net.

This volume furnishes a set of five-figure logarithms of numbers and of angular functions, together with a set of hyperbolic logarithms, in a form which can be conveniently carried in the pocket and, therefore, suitable for the work of the engineer and constructor. Only so much of the theory and use of logarithms is given as will serve to supplement the memory of the user, and to enable him to make the book useful in all practical computations which require a greater degree of precision than is attainable with the pocket slide rule. It is hoped that the presentation of such tables in this convenient form will cause them to be used for much work for which cumbersome arithmetical computations would otherwise be required, and will thus make the use of logarithms available in many places where the bulk of existing tables renders them inconvenient.

### STEAM TURBINES AND TURBO-COMPRESSORS:

Their Design and Construction. By Frank Foster. Cloth, 9 x 6 in., illus., 7 + 449 + 9 pp. Manchester, The Scientific Publishing Company. 10 shillings 6 pence net.

There is always a demand for a book on steam turbines which is not simply a popular description of existing machines, nor yet a mathematical treatise, and which is not a mere compilation from the patent records. The author states that he has tried to supply this demand with the present volume. In his opinion students should be trained to understand the influence of economic considerations on the design of machinery and to keep in mind that it is the commercial efficiency and not the thermal or mechanical efficiencies which decide the success or failure of a machine, and he has, therefore, treated the subject of turbines in a manner which is practical in the best sense of the word. Among much that is original, the subject-matter contains two new heat diagrams—one for steam and one for gases—which will be found useful in turbine design; a general method of determining the critical speed for any kind of rotor; and a method of determining the best vacuum in the condenser of either a turbine or a reciprocator, under any given conditions as to load factor and the price of coal. In the chapter on Diagrams and Calculations, the method of determining the principal quantities for turbines is explained and illustrated by examples. The application of the steam turbine for the propulsion of ships is made the subject of a special chapter. Gas turbines and turbo-compressors are briefly discussed, and an outline of turbine history is also included. The Contents are: Introductory; Descriptions of Turbines; Steam Nozzles: Disc Friction; Blades; Rotors; Governing; Bearings; Gyroscopic Action: Deflection of Discs; Critical Velocity: Balancing; Condensers; Steam Turbine Performance; Marine Turbines: Turbo-Compressors: Gas Turbines; Diagrams and Calculations; Construction: Miscellaneous; History. There is an appendix containing data and formulas for use in calculations in connection with steam-turbine work, and an index of nine pages.

### GENERAL SPECIFICATIONS FOR STEEL RAILROAD BRIDGES

And Viaducts. By Theodore Cooper, M. Am. Soc. C. E. New and revised ed. Paper, 9½ x 7 in., 36 pp. New York, The Engineering News Publishing Co., 1906. 50 cents net.

This edition is the tenth revision—the seventh of those published in the author's name—since these specifications were first prepared more than twenty-five years ago. These revisions have been made from time to time in order to meet the requirements of increasing train loads and the improvements in materials and methods of construction. While the specifications are "general"

* Unless otherwise specified, books in this list have been donated by the publisher.

in their requirements, they are intended more especially to cover ordinary bridges or those resting on two supports only. For special structures or for those having special or unusual conditions and requirements, they should be supplemented by clauses suitable for the particular case. The author's experience has shown that plans and structures which comply fully with the specifications prepared for them are limited in number. As railroads now demand bridges capable of carrying the maximum possible train loadings, not only safely, but rigidly, bridges of the future must necessarily be better than those of the past.

**ELECTRICAL ENGINEERING**

In Theory and Practice. By G. D. Aspinwall Parr. Cloth, 9 x 6 in., illus., 8 + 447 pp. London, Macmillan and Co., Limited, 1906. $3.25 net.

The author states that this work differs considerably from other works of a similar nature published previously. It includes fundamental matter which, although elementary, is important and should be known by an electrical engineer. The subjects are arranged in the order in which they may be read with the most profit. While endeavoring to keep the book fully up to date, every effort has been made to exclude all historical matter and obsolete appliances, except those in which important principles are contained. Numerous references to current technical periodical literature are made, and all questions set for the technological examinations of the City and Guilds of London Institute, in the Preliminary, Ordinary and Honours Grades of Electro-Technology, are given at the end of the various chapters to the subject-matter of which they particularly relate. The Contents are: Magnetism (Fundamental Principles); Electricity (Statical), Fundamental Phenomena; Electricity (Current), Fundamental Principles and Units; Electrical Resistance; Electro-Magnetism; Electro-Static and Electro-Magnetic Induction; Electrical and Magnetic Instruments; Electric Incandescent Lamps; Electric Arc Lamps; and The Production of Electro-Motive Force (Thermo-Generators, Primary Cells, Secondary Cells). There is an index of seven pages.

**STRAY CURRENTS**

From Electric Railways. By Dr. Carl Michalke. Translated and Edited by Otis Allen Kenyon. Cloth, 8 x 6 in., illus., 8 + 101 pp. New York, McGraw Publishing Company, 1906. $1.50 net.

Many valuable and thoroughly scientific reports on the subject of electrolysis—the results of extensive investigations in Europe—have appeared in the various foreign technical periodicals. As it is not always possible, however, to consult these periodicals, the author has collected the material and issued it in its present form with the hope that it will inspire further investigation and discussion, which will do much toward enlightening those who are interested in the corrosive action of return currents and in its prevention. He does not claim that any general method of preventing such disturbances is given, since there are too many factors, depending on local conditions, which enter in the problem, but information on various parts of the subject can easily be obtained from the contents of the book. The subject has been treated mathematically in part, since the means of preventing and controlling the danger rest upon a knowledge of the distribution and strength of the stray currents. All the calculations in the text, however, are elementary in character, the rigorous mathematical treatment being given in the foot-notes. The translator has added an extensive bibliography and a few foot-notes from American practice. The Contents are: Introduction; Stray Currents with Uniform Current Load on the Rails; Stray Currents with Uniformly Increasing Current Loads on the Rails; Resistance Values; Distribution of Potential in the Earth; Corrosion Currents; Corrosion Currents Which do not Come from Railways; Corrosion; Measurements; Preventative Measures; Other Disturbances Caused by Stray Currents; Conclusions. There is an index of two and one-half pages.

**GENERAL SPECIFICATIONS FOR STEEL RAILROAD BRIDGES**

And Structures; With a Section Making Them Applicable to Highway Bridges and Buildings. Prepared under the Direction of Virgil G. Bogue, M. Am. Soc. C. E., by Albert W. Buel. Paper, 8¾ x 6 in., 61 + 17 pp. New York, The Engineering News Publishing Company, 1906. 50 cents net.

It is stated in the preface that these specifications have been written with the purpose of combining such rules, governing the design, workmanship and quality of material, that steel structures built in accordance with them will be

first-class in every respect, up to the highest standard of present practice, and, at the same time, as economical as is consistent with such results. As many different types of railroad bridges, swing spans, highway bridges and railroad buildings and sheds, have been built with success, under specifications not differing materially from these here presented, the author hopes that, rewritten in a general form and revised, after three years' use, they may be of assistance and value to bridge builders. Innovations, that have not been fully demonstrated as improvements on older forms, have been avoided; thus, the Cain-Launhardt formula, for instance, has been retained in preference to the Snyder-Thompson formula, but it has been changed so that it governs the proportions of all details, including the bearing and shear on rivets, pins and web plates. This is thought to be an improvement on the older form of this formula, and to be more rational. The "Quality of Material" given is first class in every respect, but is such as can be readily obtained in any American mill, without extra cost. The "Workmanship" can be complied with in any well-equipped shop. The new uniform live load which may be substituted for the Cooper concentrated loadings is presented for the use of engineers who prefer to use uniform loads, rather than wheel loads, in their computations. No claim is made for originality in these specifications, and it is believed that their clearness, wide range of application and the number of points covered will fully compensate for their length. The Contents are: Section I, Preliminaries; Section II, General Requirements; Section III, Loads; Section IV, Working Stresses; Section V, General Details; Section VI, Quality of Material; Section VII, Workmanship; Section VIII, Painting; Section IX, Inspection; Section X, Erection; Section XI, Highway Bridges and Buildings. There is no index.

### HANDBOOK OF MATHEMATICS

For Engineers and Engineering Students. By J. Claudel. From the Seventh French Edition. Translated and Edited by Otis Allen Kenyon. Cloth, 10 x 6 in., illus., 9 + 708 pp. New York, McGraw Publishing Company, 1906. $3.50 net.

The need of a mathematical handbook, containing the practical part of every branch of the subject, has long been felt by professional men. It is stated that, although this book is intended primarily as a reference book, it is also well adapted to home study. The whole subject of mathematics is here developed and covered without repetitons, and a system of cross references, completely inter-connecting all parts of the book, has been used. The greater part of the material has been taken from Claudel's "Introduction à la Science de l'Ingénieur," a pocket-book for engineers, architects, etc., which has passed through seven editions in France. To the translation from Claudel's book, chapters on United States weights and measures, annuities, insurance, bank discount, etc., and various tables, have been added. The Contents are: Part I, Arithmetic; Part II, Algebra; Part III, Geometry; Part IV, Trigonometry; Part V, Analytic Geometry; Part VI, Elements of Calculus. There is no index.

### FOWLER'S ARCHITECTS' AND BUILDERS' HANDBOOK.

A Synopsis of Practical Rules, Tables and Data specially compiled for the Use of Architects, Builders, Plumbers, Painters, Decorators, and Students in Technical Schools. Leather, 6 x 4 in., illus., 72 + 526 pp. Manchester, Scientific Publishing Co. 3 shillings 6 pence.

The building and allied trades have long since felt the need of a comprehensive and cheap handbook, and the author hopes that this volume will meet that need. He states that it is not a text-book on any particular building trade, but that it contains such a summary of the leading features in connection with the majority of them, as will make it a valuable pocket or desk companion. A great deal of condensation has been necessary in its compilation, but care has been taken that no essential information has been omitted. The notes and information on the various subjects dealt with have been made as practical as possible. Illustrations have been freely used, and no trouble has been spared in making them clear and intelligent. For convenience of reference the book has been divided into various sections and equipped with a copious index. The sections comprise, in addition to the general rules and tables more or less applicable to all trades, specially detailed information in respect to brick work, slating and tiling, masonry, timber, joinery and carpentry, roof and floor constructions, plumbing, heating and ventilating arrangements, water supply, sanitation, painting and decorating, electric lighting, estimating, various by-laws and regulations respecting building operations, styles of architecture, corrosion and protection of metal structures, etc.

**CATECHISM ON PRODUCER GAS.**

By Samuel S. Wyer. Cloth, 7 x 5 in., illus., 3 + 42 pp. New York, McGraw Publishing Company, 1906. $1 net.

The author states that the object of this volume is to give, in the form of questions and answers, a brief discussion of the types of apparatus and the methods used in the manufacture of producer gas; together with an outline of its history, its present and future uses and its advantages. The Contents are: Fundamental Definitions; Producer Gas and Its Manufacture; History and Status of Producer Gas; Uses of Producer Gas; Cleaning of Producer Gas; Handling of Gas Producers; and Construction of Gas Producers.

Gifts have also been received from the following:

Alumni Assoc. of the Stevens Inst. of Tech. 1 pam.
Am. Inst. of Elec. Engrs. 1 bound vol.
Assoc. of Am. Portland Cement Mfrs. 1 pam.
Ball, C. B. 1 bound vol.
Berlin Kgl. Technische Hochschule. 1 pam.
Buffalo, Rochester & Pittsburgh Ry. Co. 1 pam.
Cape Soc. of Civ. Engrs. 1 pam.
Central of Georgia Ry. Co. 1 pam.
Chicago, Ill.—Bureau of Statistics and Municipal Library. 1 pam.
Chicago & North Western Ry. Co. 1 pam.
Colby, A. L. 1 pam.
Comm. des Annales des Ponts et Chaussées. 1 pam.
Conn.—State R. R. Commrs. 1 bound vol.
Denver & Rio Grande R. R. Co. 1 pam.
Dyckerhoff & Söhne. 1 vol.
Eng. Assoc. of New South Wales. 2 bound vol.
Glasgow, Scotland—Tramways Committee. 1 pam.
Great Britain—Patent Office. 15 vol., 3 pam.
Hannover Kgl. Technische Hochschule. 1 pam.
Hatt, W. K. 1 pam.
Hering, Rudolph. 1 pam.
India—Under Secy. to Govt. 1 bound vol., 2 vol.
Indiana—Dept. of Geology and Natural Resources. 1 bound vol.
Inst. of Civ. Engrs. 1 pam.
Lawrence, Mass.—Water Board. 1 pam.
Liverpool, Eng. Soc. 1 vol.
Lynn, Mass.—City Messenger. 1 bound vol.
McGill Univ. 2 bound vol.
Midland Ry. Co. 1 pam.
Moore, Robert. 1 pam.
National Assoc. of Mfrs. of Sand-Lime Products. 1 vol., 1 pam.
New South Wales—Public Works Dept. 10 vol.
New South Wales—Ry. Commrs. 1 pam.
*New York City Record.* 1 bound vol.
North, E. P. 2 pam.
Northampton, Mass.—Mayor. 1 bound vol.
Ohio—Geol. Survey. 1 pam.
Ohio Eng. Soc. 1 vol.
Ottawa, Ont.—Supt. of Immigration. 1 vol.
Platt, T. C. 2 vol.
Quinette de Rochemont, E. T. 1 pam.
St. John, N. B.—Water and Sewerage Dept. 1 pam.
Soc. Belge des Ingénieurs et des Industriels. 3 pam.
Soc. of Arts. 1 pam.
U. S. Bureau of Soils. 1 bound vol.
U. S. Commr. of Education. 2 bound vol.
U. S. Engr. School. 1 pam.
U. S. Forest Service. 1 pam.
U. S. Geol. Survey. 18 pam.
U. S. Interstate Commerce Comm. 1 pam.
U. S. Lake Survey Office. 1 pam., 4 maps.
U. S. Library of Congress. 1 pam.
U. S. National Museum. 1 pam.
U. S. Office of Exper. Stations. 1 pam.
U. S. Senate Committee on Interoceanic Canals. 4 vol.
U. S. War Dept. 18 specif.
Univ. of Pennsylvania. 1 pam.
Western Ry. Club. 1 bound vol.
Western Soc. of Engrs. 1 pam.
Wilmington, Del.—Water Dept. 1 vol.
Woburn, Mass.—City Govt. 1 bound vol.

## BY PURCHASE.

**Assainissement des Villes;** Distributions d'Eau. Par A. Debauve, Ed. Imbeaux. Vol. 1–4. Paris, H. Dunod et E. Pinat, Éditeurs, 1906.

**The National Cyclopædia of American Biography;** Vol. 13. New York, James T. White & Co., 1906.

**Mittheilungen aus dem Mechanisch-Technischen Laboratorium** der K. Technischen Hochschule München. Gegründet von J. Bauschinger. Neue Folge. Herausgegeben von August Föppl. München, Theodor Ackermann, 1906.

**Trow's General Directory,** for the year ending July 1st, 1907. New York, Trow Directory Company, 1906.

**Mechanics' and Engineers' Pocket-Book.** By Chas. H. Hsawell. ed. 71. New York, Harper & Brothers, 1905.

**Turbines.** By W. H. Stuart Garnett. London, George Bell and Sons, 1906.

## SUMMARY OF ACCESSIONS.

From August 6th to September 8th, 1906.

| | |
|---|---|
| Donations (including 12 duplicates)..... | 147 |
| By purchase..... | 9 |
| Total..... | 156 |

## MEMBERSHIP.

### ADDITIONS.

| | | Date of Membership. |
|---|---|---|
| **MEMBERS.** | | |
| McMORRIS, DANIEL WEBSTER. U. S. Asst. Engr., Corregidor, Philippine Islands | | May 2, 1906 |
| RUSSELL, RICHARD LORD. Chf. Engr. and Supt. for Charles Cranford, Gen. Contr., Foster Ave. and East 16th St., Brooklyn, N. Y. | Jun. | Feb. 5, 1895 |
| | Assoc. M. | April 3, 1901 |
| | M. | Sept. 4, 1906 |
| STICKNEY, GEORGE FETTER. Barge Canal Office, DeGraaf Bldg., Albany, N. Y. | Jun. | May 1, 1894 |
| | Assoc. M. | April 5, 1899 |
| | M. | Sept. 4, 1906 |
| **ASSOCIATE MEMBERS.** | | |
| ARCHER, AUGUSTUS ROWLEY. Div. Engr., Hudson Companies, 98 Hudson St., Jersey City, N. J | | April 4, 1906 |
| BAXTER, DAVID ELDER. 32 West 60th St., New York City | Jun. | May 2, 1899 |
| | Assoc. M. | July 9, 1906 |
| FARNHAM, ROBERT, Jr. 316 New Jersey Ave., S. E., Washington, D. C | | July 9, 1906 |
| FERRADAS, RAMIRO FRANCISCO ANTONIO. Care, Hering & Fuller, 170 Broadway, New York City | Jun. | Jan. 3, 1905 |
| | Assoc. M. | Mar. 7, 1906 |
| GRAVES, WALTER JOSEPH. Jun. Engr., U. S. Lake Survey, 33 Campau Bldg., Detroit, Mich | | July 9, 1906 |
| HAEHL, HARRY LEWIS. Asst. Engr., Bay Cities Water Co., 1368 Geary St., San Francisco, Cal. | Jun. | Oct. 6, 1903 |
| | Assoc. M. | July 9, 1906 |
| HYDE, HOWARD ELMER. 302 W. Seneca St., Ithaca, N. Y. | | April 4, 1906 |
| NIAL, WILLIAM AUGUSTINE. 72 West 126th St., New York City | | July 9, 1906 |
| POLK, ARMOUR CANTRELL. Asst. Supt., Power House Constr. (Sanderson & Porter), P. O. Box 321, New Orleans, La. | Jun. | Oct. 6, 1903 |
| | Assoc. M. | May 2, 1906 |
| WHITMAN, EZRA BAILEY. Div. Engr., Disposal Plant, Baltimore Sewerage Comm., Clifton Ave. and 8th St., Walbrook, Baltimore, Md | Jun. | Feb. 3, 1903 |
| | Assoc. M. | Feb. 7, 1906 |
| **JUNIORS.** | | |
| BAKER, PERCIVAL STEVENS. 65th Ave. and Camac St., Oak Lane, Philadelphia, Pa. | | Sept. 4, 1906 |
| BECKER, ELVIN JAY. Lenox Dale, Mass | | April 3, 1906 |
| GILLAND, THOMAS OMAR. 5334 Wayne Ave., Germantown, Philadelphia, Pa. | | Sept. 4, 1906 |

JUNIORS (*Continued*).

| | Date of Membership. |
|---|---|
| GILLELEN, FRANK. Broadway Bank, Los Angeles, Cal... | May 1, 1906 |
| HAYES, CHARLES EDWARD. Res. Engr., Great Northern Ry., Donnybrook, N. D. (Res., 359 Locust St., Detroit, Mich.)..... | Mar. 6, 1906 |
| HOWIE, HOWARD BENSON WILBERFORCE. City Engr's. Office, Chattanooga, Tenn..... | Mar. 6, 1906 |
| IRWIN, ORLANDO WILLIAM. The Clayton, Hoffman and Gloyd Sts., Cleveland, Ohio..... | Sept. 4, 1906 |
| PARSONS, AUGUSTUS TABER. Pulga, Butte Co., Cal..... | June 5, 1906 |
| PEABODY, LIONEL HENRY, JR. 610 Church St., Lynchburg, Va..... | Feb. 6, 1906 |

## REINSTATEMENTS.

ASSOCIATE MEMBERS.

| | Date of Reinstatement. |
|---|---|
| ADAMS, ARTHUR. P. O. Box 691, Sault Ste. Marie, Mich. | Sept. 4, 1906 |

## RESIGNATIONS.

JUNIORS.

| | Date of Resignation. |
|---|---|
| WILSON, JAMES ARTHUR..... | Sept. 4, 1906 |

## DEATHS.

COOPER, EDWARD. Elected Fellow, December 10th, 1885; died February 25th, 1905.

JACKSON, JONES MUMFORD. Elected Member, September 1st, 1886; died August 31st, 1906.

TATNALL, GEORGE. Elected Member, May 3d, 1899; died September 13th, 1906.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(July 28th to September 8th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles, references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass. 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefeuille Economique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Building, Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.

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Eclairage Electrique des Trains de Chemin de Fer par le Système l'Hoest-Pieper.* L'Hoest. (32) April.
Notes de Voyage en Amérique; Quatrième Partie.* (Locomotives, rolling stock, etc.). Asselin and Georges Collins. (38) (July.)
Le Transport des Matières Dangereuses. Tabariés de Grandsaignes. (33) July 14.
Considerations Générals sur la Facilité de Descente des Tirefonds à leur Mise en Place; Appareil d'Expérimentation.* M. E. Perroud. (38) Aug.
Les Nouvelles Locomotives Compound à deux Bogies Moteur de la Compagnie des Chemins de Fer du Nord.* A. Morizot. (34) Aug.

*Illustrated.

**Railroad—(Continued).**

Installations de Chargement Mécanique du Charbon dans les Dépôts de Locomotives.* (33) Aug. 11.
Préparateur d'Itinéraires, Système J. Forestier, avec Commande à Distance et Enclenchement des Appareils de Voie et des Signaux.* R. Coupon. (33) Aug. 18.

**Railroad, Street.**

A Suggested Solution of Metropolitan Transit.* W. Jones Cuthbertson. (Paper read before the Technical Soc. of the Pacific Coast.) (1) June.
A Reversible Booster and its Running.* C. Turnbull. (77) July.
A New Method of Automatic Boosting.* Max J. E. Tilney. (77) July.
Cement Testing Laboratory, Philadelphia Rapid Transit Company. (40) July 27; (72) Aug.
The New York Subway.* (21) Aug.
Remedies for Electrolysis.* A. A. Knudson. (10) Aug.
Sansom Street Substation, Philadelphia Rapid Transit Company.* (72) Aug.
Switch and Transformer House for Brunots Island Power Station, Pittsburg Railways Company.* (72) Aug.
The Track Construction of Underground Railways.* (13) Aug. 2.
The Reconstruction of the Clinton Street Railway System, Clinton, Iowa.* (17) Aug. 4.
Guarding Against Electrolysis of Underground Pipes. Putnam A. Bates. (14) Aug. 4; (15) Aug. 31.
The Market Street Elevated Railway, Philadelphia.* (14) Aug. 11.
Gear Practice on the Interborough System.* (17) Aug. 18.
Appendix to Report on Electrolysis at Karlsruhe.* F. Haber. (Abstract of Report, Electrolysis Comm. of the German Assoc. of Gas and Water Engrs.) (66) Aug. 28.
Oiling of Roadbeds on the Brooklyn Rapid Transit System.* (17) Sept. 1.
Construction and Maintenance of Street Railway Track. M. Neilson. (Abstract of paper read before the Canadian Street Ry. Assoc.) (13) Sept. 6.

**Sanitary.**

The Pollution of the Tidal Waters of New York City and Vicinity. George A. Soper. (Paper read before the Boston Soc. of Civ. Engrs.) (1) June.
Garbage Disposal by Reduction Methods.* D. Robert Yarnall. (2) July.
Purification of Slaughter-House Refuse at Zerbst, Germany. Wm. H. Schladitz. (60) Aug.
The Assessment of Drainage Districts.* L. E. Ashbaugh. (4) Aug.
Heat Losses and Heat Transmission. Walter Jones. (Paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (70) Aug.
Review of the History of the Septic Tank. J. W. Alvord, M. Am. Soc. C. E. (Reprint from Proc. Illinois Soc. of Engrs. and Surv.) (13) Aug. 2.
A New Form of Primary Contact Bed. (14) Aug. 11.
The Cape May Improvements (Land Reclamation).* (14) Aug. 11.
The Disposal of the Sewage of Paterson, N. J.* Allen Hazen. (14) Serial beginning Aug. 11.
The Trickling Filter at the Sewage Experiment Station of the Massachusetts Institute of Technology.* C. E. A. Winslow and Earle B. Phelps. (13) Aug. 16.
The Testing of Clay and Concrete Pipes.* (14) Aug. 18.
The Heating Plant of Calvary Church, Pittsburg.* H. S. Knowlton. (14) Aug. 18.
A Combined Municipal Refuse Destructor and Electric Generating Station.* (14) Aug. 18.
A Rubbish Incinerator Plant in Brooklyn.* (14) Aug. 25.
Heating and Ventilating Plant of the Hotel St. Regis, N. Y.* (14) Aug. 25.
Heating and Ventilating Equipment of the Carnegie Branch Library No. 1, St. Louis, Mo.* (14) Sept. 1.
Sludge Treatment in Relation to Sewage Disposal. John D. Watson. (Paper read before the Assoc. of Mun. and County Engrs.) (14) Sept. 1.
Report of a London Engineer on Sewage Disposal at Toronto, Ont. (13) Sept. 6.
Abattoir Public de la Ville d'Offenbach-sur-le-Main (Allemagne).* Ch. Dantin. (33) July 28.
L'Incinération des Ordures Ménagères.* W. Lagny. (35) Serial beginning Aug.

**Structural.**

The Morton Memorial Laboratory of Chemistry of Stevens Institute of Technology.* F. J. Pond. (8) July; (19) Sept. 8.
Methods of Testing Cement for Waterproofing Properties.* W. Purves Taylor. (Paper read before the Amer. Soc. for Testing Materials.) (67) July.
The Determination of the Specific Gravity of Cement.* Richard K. Meade. (Paper read before the Amer. Soc. for Testing Materials.) (67) July.

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* Illustrated.

**Structural—(Continued).**

British Fire Appliances. (12) Serial beginning July 20.
The United States Express Co.'s Building, New York City.* (14) July 28.
A Method of Mixing and Laying Bituminous Concrete for Mill Floors.* C. H. Chadsey. (13) Aug. 2.
Examples of the Protection of Chimneys against Lightning.* (13) Aug. 2.
Standard Specifications for the Grading of Structural Timbers.* (Report of Com. of Amer. Soc. for Testing Materials.) (14) Aug. 4.
A Buffalo Foundation Problem: The New York State Steel Company's Solution.* (20) Aug. 9.
Molecular Structure of Metals.* J. A. Ewing. (Abstract of paper read before the British Assoc.) (47) Aug. 11; (73) Aug. 10; (26) Aug. 24.
Tension Tests of Steel Angles with Various Types of End Connection.* Frank P. McKibben. (Paper read before the Amer. Soc. for Testing Materials.) (14) Aug. 11.
Fire, Fire Risks and Fire Prevention. Vivian B. Lewes. (29) Aug. 17.
Mistakes in Waterproofing. Edward W. DeKnight. (Abstract of paper read before Amer. Soc. for Testing Materials.) (14) Aug. 18.
The San Francisco Lesson.* F. W. Fitzpatrick. (19) Serial beginning Aug. 18.
Steel Work in the Apthorpe Apartment House.* (14) Aug. 25.
Comparative Tests of Cement Mortar Showing the Relative Effects of Three Different Sands. A. Black. (13) Aug. 30.
Building Materials in the San Francisco Earthquake.* (60) Sept.
A Rapid General Method for the Calculation of Reinforced Concrete Sections. Richard T. Dana. (14) Sept. 1.
Large Derricks for the Erection of Steel Buildings.* (13) Sept. 6.
La Prise du Ciment Portland. Ed. Candlot. (Tr. from *Concrete.*) (84) July.
L'Esthétique dans les Ouvrages en Ciment Armé.* P. Henrivaux. (Extract from *Journal Technique et Industriel.*) (84) July.

**Topographical.**

The Tractrigraph, an Improved Form of Hatchet Planimeter.* A. L. Menzin. (13) Aug. 9.

**Water Supply.**

Economies to be Derived from the Utilization of Water Powers of Low Head in the Central West.* Dugald C. Jackson. (42) July.
Report of the Commission of the German Gas and Water Companies for the Investigation of Earth Currents. (73) July 20.
Water Supply in a Dairy District.* William Phelps. (Paper read before the British Assoc. of Water-Works Engrs.) (66) July 24.
Disinfection as a Means of Water Purification. George C. Whipple. (Paper read before the Amer. Water-Works Assoc.) (14) July 28.
Tropical Waters and their Purification. H. G. Foster-Barham, Assoc. M. Inst. C. E. (Paper read before the British Assoc. of Water-Works Engrs.) (66) July 31.
Expanding Water Supply Systems. J. T. Fanning. (Abstract of paper read before the Amer. Waterworks Assoc.) (60) Aug.
A New Slow Sand Filter for Lawrence, Mass.* J. Rodney Ball. (60) Aug.
The Philadelphia High Pressure Water System. F. L. Hand. (Abstract of paper read before the Amer. Waterworks Assoc.) (60) Aug.
An Arbitration on the Value of a Waterworks. Albert H. Wehr. (Abstract of paper read before the Amer. Waterworks Assoc.) (60) Aug.
High Pressure Sluicing Gates.* M. O. Leighton, Assoc. M. Am. Soc. C. E. (Comp. from Reports of Supervising Engrs., U. S. Reclamation Service.) (4) Aug.
Additional Water Supply for Johannesburg, South Africa. (13) Aug. 2.
Guarding Against Electrolysis of Underground Pipes. Putnam A. Bates. (14) Aug. 4.
Sale of Water Power from the Power Company's Point of View. C. E. Parsons. (Paper read before the St. Ry. Assoc. of N. Y.) (14) Aug. 11.
A Sand Trap for Irrigating Ditches. H. A. Crafts. (14) Aug. 11.
The New Water Power Plant of the Blackstone Manufacturing Co.* (14) Aug. 11.
On the Section of Weirs. W. G. Bligh, M. Inst. C. E. (12) Serial beginning Aug. 17.
Laying a Submerged Water-Main under the River Ouse.* W. H. Humphreys. (Paper read before the British Assoc. of Water-Works Engrs.) (66) Aug. 21.
The Baisleys, Springfield, Forest Stream and Hempstead Filter Plants, Borough of Brooklyn, New York. (13) Aug. 23.
The Pipe Line of the New Gravity Water Supply of Lynchburg, Va.* (14) Sept. 1.
Usines Hydro-Electriques de Vizzola et de Turbigo (Lombardie).* (33) July 21.

*Illustrated.

**Water Supply—(Continued).**

La Captation des Eaux à Forte Profondeur; Note sur les Projets d'Extension des Ouvrages de Captation et d'Adduction de la Ville de Liége.* L. Brouhon. (30) Aug.

Les Eaux Alimentaires de Liége.* Edmond G. Detienne. (30) Aug.

L'Usine Hydro-Electrique de la Siagne à Saint-Cézaire (Alpes-Maritimes).* P. Chignaterie. (33) Aug. 25.

**Waterways.**

Reinforced Concrete Casing for the Protection of Piles in Wharf Construction.* F. A. Koetitz. (Paper read before the Technical Soc. of the Pacific Coast.) (1) May.

The New Sea-Wall at Annapolis, Md.* Harrison W. Latta. (2) July.

The Thames Conservancy. (12) Serial beginning July 20.

The Chalmette Docks of the New Orleans Terminal Co. (14) Serial beginning July 28.

Electrical Canal Towage in Germany.* (27) Aug. 11.

A Determination of Actual Earth Pressure from a Coffer Dam Failure. Thos. C. J. Baily, Jr., M. Am. Soc. C. E. (13) Aug. 16.

Harbor Improvement at San Pedro and Wilmington, California.* (13) Aug. 16.

Protecting Piles from the Teredo.* (15) Aug. 17.

Subaqueous Rock-Cutting. (11) Aug. 17.

Mattress Revetments on the Mississippi River.* Harry N. Howe. (14) Aug. 18.

The Stability of Sea Walls. D. C. Serber. (13) Aug. 23.

A New Type of Sixty-Foot Summit Level Canal for Panama.* W. F. Cleveland. (46) Sept. 1.

Cost of Making and Placing Reinforced Concrete Piles at Atlantic City, N. J.* (13) Sept. 6.

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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## ADDITIONAL INFORMATION ON THE DURABILITY OF WOODEN STAVE PIPE.

By Arthur L. Adams, M. Am. Soc. C. E.

To Be Presented October 17th, 1906.

Ten years ago the writer made a special study of wooden stave pipe with reference to its suitability for conveying water under pressure, and the principles governing its economic design. The result of those studies he has previously laid before this Society.* A description of the use of 7½ miles of this class of pipe at Astoria, Ore., has also appeared in the *Transactions*.

That this pipe at Astoria has proven deficient in durability, in defiance of all preconceived ideas as to what may be expected of wood when subject to constant water pressure and buried in the earth, is certainly somewhat startling, but nevertheless true, and the writer deems it a duty to the profession that the facts be made known. In order that what is stated herein may be readily followed, a profile (Fig. 1) of the pipe line in question is submitted, and for full information as to the extreme care with which this line was designed and built, reference is made to the writer's paper, entitled "The Astoria City Water-Works."†

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* "Stave Pipe—Its Economic Design and the Economy of Its Use." By Arthur L. Adams. *Transactions*, Am. Soc. C. E., Vol. XLI, p. 27.

† *Transactions*, Am. Soc. C. E., Vol. XXXVI, p. 1.

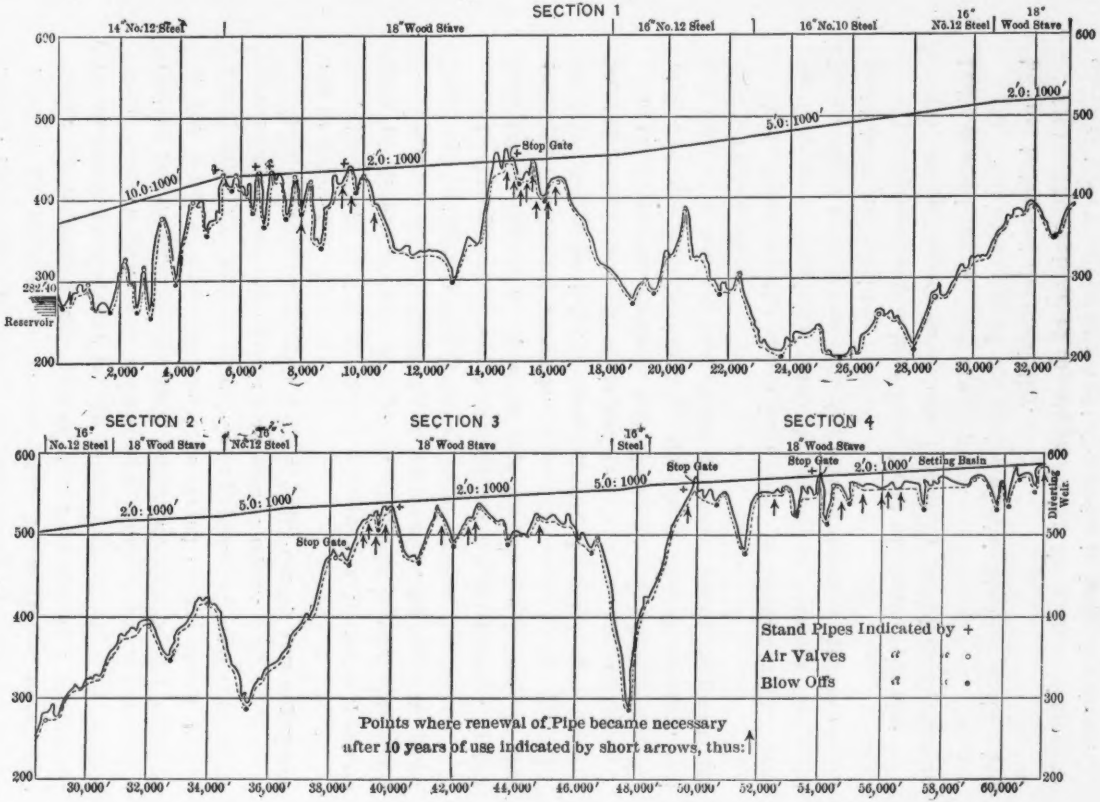

SECTION 1
14" No.12 Steel
18" Wood Stave
16" No.12 Steel
16" No.10 Steel
16" No.12 Steel
18" Wood Stave
10.0:1000'
2.0:1000'
Stop Gate
5.0:1000'
2.0:1000'
Reservoir
282.40
600
500
400
300
200
2,000' 4,000' 6,000' 8,000' 10,000' 12,000' 14,000' 16,000' 18,000' 20,000' 22,000' 24,000' 26,000' 28,000' 30,000' 32,000'
SECTION 2
16" No.12 Steel
18" Wood Stave
16" No.12 Steel
2.0:1000'
5.0:1000'
Stop Gate
SECTION 3
18" Wood Stave
16" Steel
2.0:1000'
5.0:1000'
Stop Gate
SECTION 4
18" Wood Stave
Stop Gate
2.0:1000'
Setting Basin
Diverting Weir
Stand Pipes Indicated by +
Air Valves a ○
Blow Offs a ●
Points where renewal of Pipe became necessary after 10 years of use indicated by short arrows, thus:
30,000' 32,000' 34,000' 36,000' 38,000' 40,000' 42,000' 44,000' 46,000' 48,000' 50,000' 52,000' 54,000' 56,000' 58,000' 60,000'

FIG. 1.

The staves of the pipe in question had deteriorated so much after ten years' use, that, during 1905, very extensive renewals and repairs became imperative, involving an expenditure of more than one-third of the original cost of the pipe. These repairs were made under the immediate direction of Mr. Lars Bergsvik who served as an Assistant Engineer on the original construction of the Astoria Water-Works. The information herein contained has been derived from him, from personal interviews with several members of the Water Commission who have served on the Board continuously from the beginning, and from personal inspection of many of the staves removed during the process of repair.

The salient and important facts brought out by this experience are as follows:

(1).—Staves, which are constantly subject to water pressure from within and are buried in the ground, may be very short-lived.

(2).—The magnitude of the water pressure, beyond a moderate head, has had little or no influence in preserving the timber.

(3).—The pipe laid above ground has not deteriorated to any considerable extent, nor has the pipe laid in the tunnels leading from the distributing reservoir.

(4).—Where buried, its durability has depended upon the soil conditions and the depth of backfill.

(5).—When the depth of backfill has exceeded 2 ft. above the pipe, and the material has been free from vegetable matter, and has been of a fine and impervious character, much less deterioration has taken place.

(6).—Wherever the staves have been in contact with loamy earth or earth containing vegetable matter, or wherever they have been covered with porous material, or to a depth of less than 2 ft., rapid decay has resulted.

(7).—Decayed staves have been found all around the pipe.

(8).—Sound staves have been frequently found contiguous to badly decayed staves.

(9).—The character of the grain, whether slash or grain edge, has not influenced the durability.

(10).—The bruising of the staves during the process of erection seems to have been one of the chief agencies in hastening decay.

(11).—Decay has been confined to the outside of the pipe.

(12).—The pipe has not usually shown leakage as long as sound wood has remained in excess of ¼ in. in thickness.

(13).—The malleable cast band fastenings have been found to be in good condition.

(14).—The bands, $\frac{7}{16}$ in. in size, have been considerably corroded save where secured by the nut, but all have been used again by placing the nut in its original position.

As to the future of the pipe, Mr. Bergsvik gives the following opinion:

"The pipe in the Second and Third Sections, 2½ miles (Fig. 1), is nearly all buried in fine-grained sand, and will last perhaps 10 years more by giving it a general repairing, say 5 years hence; but the greater part of the First and Fourth Sections will have to be replaced, I think, in about 4 years."

Table 1 shows the extent of the repair and replacement work performed. In explanation, it may be said that, where actual reconstruction was unnecessary, the staves on the bottom of the pipe were not generally disturbed, it being thought better economy to renew them only as leakage rendered it necessary.

Staves having a depth of decay of less than ½ in. were not disturbed. When no repairs were required for a continuous length of 75 ft. or more, the pipe was included in the third section of Table 1, as "in fairly good condition." Shorter lengths were included in the first section, as "requiring partial substitution of new staves."

TABLE 1.

| | Section 1. | | Section 2. | | Section 3. | | Section 4. | |
|---|---|---|---|---|---|---|---|---|
| | Linear feet. | Percentage of whole. | Linear feet. | Percentage of whole. | Linear feet. | Percentage of whole. | Linear feet. | Percentage of whole. |
| 1.—Pipe requiring partial substitution of new staves | 6 850 | 54 | ..... | ..... | 2 200 | 21 | 6 350 | 49 |
| 2.—Pipe requiring rebuilding | 1 450 | 11 | ..... | ..... | 360 | 3½ | 600 | 5 |
| 3.—Pipe uncovered and found in fairly good condition | 1 450 | ..... | 600 | ..... | 6 940 | ..... | 4 800 | ..... |
| 4.—Pipe not uncovered, but thought to be in fairly good condition | 3 050 | ..... | 3 000 | ..... | 900 | ..... | 1 200 | ..... |
| Total | 12 800 | ..... | 3 600 | ..... | 10 400 | ..... | 12 950 | ..... |
| New staves required, equivalent to feet of pipe | 1 960 | ..... | 7 | ..... | 800 | ..... | 1 500 | ..... |

At the stations noted in Table 2 (indicated on the profile, Fig. 1) were located the most important of the sections requiring rebuilding.

TABLE 2.

| Station. | Length of pipe, in feet. | Station. | Length of pipe, in feet. | Station. | Length of pipe, in feet. |
|---|---|---|---|---|---|
| No. 80..... | 40 | Nos. 157 and 158. | 128 | No. 447..... | 110 |
| " 95..... | 47 | " 160 and 162. | 108 | " 496..... | 20 |
| " 97..... | 40 | " 164 and 165. | 54 | " 526..... | 97 |
| Nos. 103 and 104. | 153 | No. 391..... | 25 | " 548..... | 30 |
| " 147 and 149. | 206 | " 393..... | 40 | Nos. 553 and 555. | 175 |
| " 150 and 152. | 140 | " 395..... | 36 | No. 560..... | 93 |
| " 152 and 153. | 108 | " 396..... | 45 | " 561..... | 84 |
| " 154 and 155. | 122 | " 416..... | 46 | " 566..... | 43 |
| No. 156..... | 30 | " 425..... | 34 | " 611..... | 36 |
| ..... | ..... | " 427..... | 24 | " 612..... | 22 |

Table 3, taken from the book record of the Astoria Water Commission, shows the total cost of repairs on the entire 12 miles of conduit, including both the stave and steel pipe:

TABLE 3.—COST OF REPAIRS ON 12 MILES OF CONDUIT.

| Year. | Cost. | Year. | Cost. | Year. | Cost. | Year. | Cost. | Year. | Cost. |
|---|---|---|---|---|---|---|---|---|---|
| 1895... | $108.58 | 1897... | $63.67 | 1899... | $46.10 | 1901... | $243.18 | 1903... | $350.18 |
| 1896... | 15.90 | 1898... | 65.50 | 1900... | 71.59 | 1902... | 314.03 | 1904... | 896.10 |

The cost of making good the damage resulting from two quite extensive land slides is included in these figures. Of the remainder, by far the greater part has been expended on the stave pipe.

The steel pipe is considered to be in fairly good condition. Perforations, however, have occurred in a few places, the total number, for the years indicated, being as follows:

1902.....7 perforations.
1903.....3 "
1904.....9 "
1905.....8 "

The total cost for repairs has been $297 for 27 perforations.

The writer hopes that the recounting of this experience with stave pipe may lead to the accumulation, through discussion by others, of much additional information on this important subject. He wishes, however, to caution any one against hastily attributing the lack of durability in the case of the Astoria pipe to the use of fir for staves instead of redwood, as he is prepared to cite an important redwood pipe line in Southern California, built at about the same time as the line under consideration, which has not shown much, if any, better results. Lack of full and exact data makes further reference to it inexpedient at the present time.

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## WORKS FOR THE PURIFICATION OF THE WATER SUPPLY OF WASHINGTON, D. C.

By Allen Hazen and E. D. Hardy, Members, Am. Soc. C. E.

To be Presented November 7th, 1906.

A sand filtration plant for the purification of the public water supply of Washington, D. C., has recently been put in service, and at present about 70 000 000 gal. of water per day are being treated.

The following is an account of the steps leading up to the construction of this plant, and a description of some of the more important and novel features of its construction and operation.

### General Arrangement of the Water-Works.

For the last fifty years the water supply of Washington has been obtained from the Potomac River at Great Falls, about 14 miles above the city. At this point the water has a low-water elevation of 150.5 ft. above mean tide.

*Aqueduct.*—The water flows through an aqueduct with a slope of 0.00015 (or 9½ in. per mile), and is 9 ft. in diameter, but some unlined tunnel sections through hard rock are larger. There are

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many interesting structures on the line of the aqueduct, among them the Cabin John Bridge, until recently the longest masonry arch in existence.

The water passes through two reservoirs before reaching its present terminus in the Washington City Reservoir. These two reservoirs have by-passes, but usually all the water flows through them. The aqueduct is under slight pressure, the level of the water in it being as much as 2 or 3 ft. above its top; the hydraulic slope, therefore, usually differs from, and is less than, the actual slope of the masonry. It must have been the original intention to use the aqueduct in this way, for the flow lines of the reservoirs are some feet above the top of the aqueduct.

*Reservoirs.*—The first reservoir, 9 miles below Great Falls, known as the Dalecarlia Reservoir, was formed by damming a natural valley. It is irregular in shape, and comparatively shallow. The second, or Georgetown Reservoir, 12 miles from Great Falls, is built with embankments on a hillside, on a rectangular plan, and is of fair depth. The city was supplied for a long time by pipes leading directly from the Georgetown Reservoir. The aqueduct and these two reservoirs were constructed by General Meigs forty-five years ago.

More recently, a tunnel has been constructed from the Georgetown Reservoir to a central point in the city near Howard University, and a third reservoir, called the Washington City Reservoir, has been built at its terminus. This tunnel is 20 756 ft. long, generally 9 ft. in diameter, lined throughout, and is in the shape of a deep inverted siphon. Under Rock Creek it is 170 ft. below the hydraulic grade, and therefore under corresponding pressure. This portion has an inner lining of flanged, cast-iron plates, filled in with concrete, and is smaller in diameter.

The capacities of the three reservoirs, from their bottoms to their nominal flow lines, are approximately 150 000 000, 150 000 000 and 300 000 000 gal., respectively, making a total storage capacity of 600 000 000 gal. As the reservoirs cannot be filled to their flow lines when the full capacity of the aqueduct is used, and cannot be drawn to their bottoms, only a part of this, roughly estimated at 300 000 000 gal., can be utilized.

*Capacity of the Aqueduct.*—The most reliable information as

to the capacity of the aqueduct from Great Falls to the city was obtained by a series of current-meter observations made by Captain (now Major) Gaillard in 1897, after raising the dam at Great Falls and thoroughly cleaning the aqueduct. He found that with the water at Great Falls at the crest of the dam, as reconstructed at Elevation 150.5, and with the water in the Georgetown Reservoir at 144, or somewhat below the level at which it has been usually carried, water would flow through the aqueduct at the rate of 76 500 000 gal. per day.

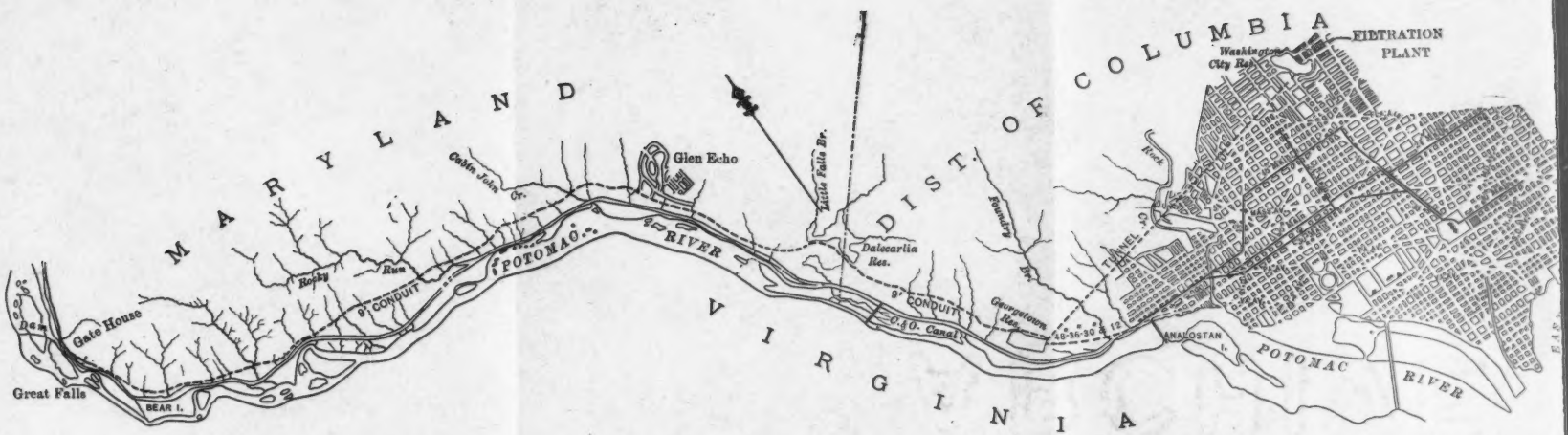
When the difference in the water levels is less, that is to say, when the water in the distributing reservoir is higher, the carrying capacity of the aqueduct is reduced; but, on the other hand, with the reservoirs in the city drawn below their usual levels, and with the water at Great Falls higher, the carrying capacity is considerably increased.

For practical purposes it has been considered that 75 000 000 gal. represents the full carrying capacity of the aqueduct, as this is the largest quantity which can be drawn without reducing the water levels to a greater extent than has been thought advisable.

Since the filters have been in operation the quantity of water passing through the aqueduct has been known with accuracy, and from these records the resistances of the different parts of the aqueduct and tunnel are known with greater accuracy. The results obtained check substantially Major Gaillard's work and the further computations based upon it which have been used for estimating the discharge in the interval.

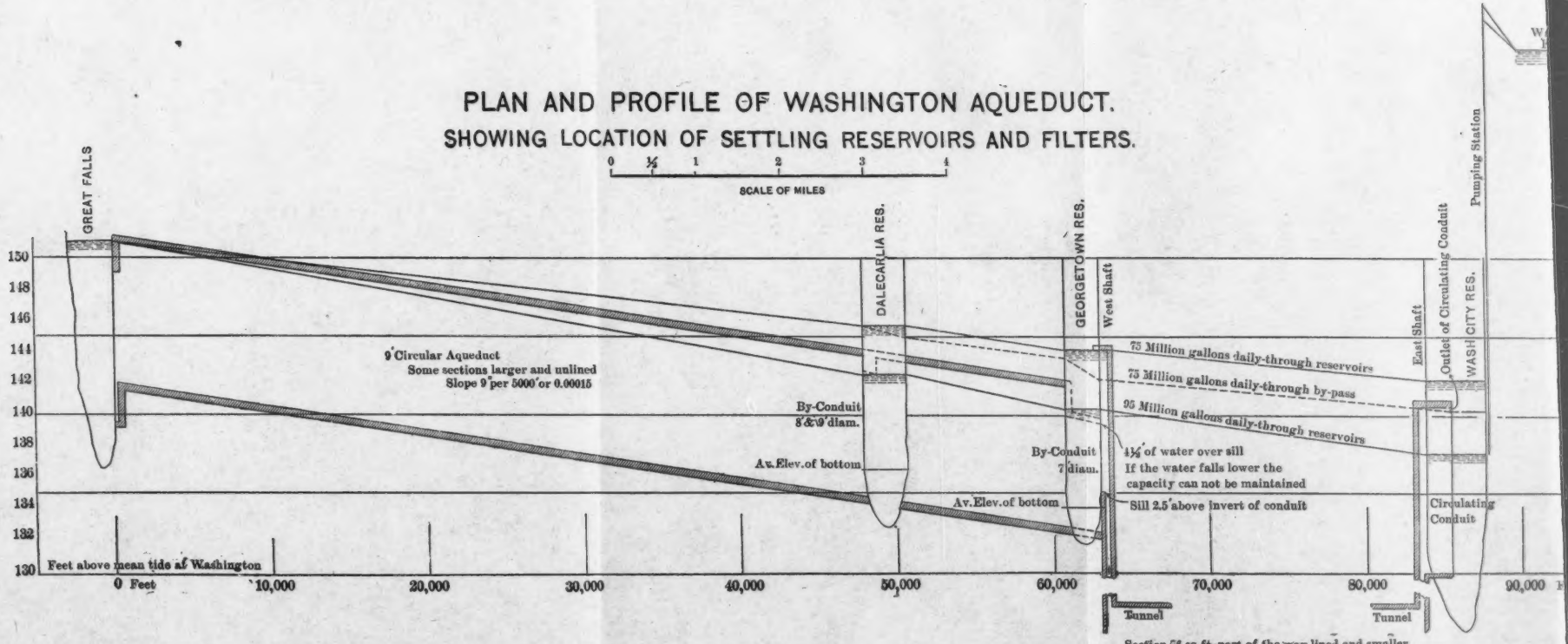
*High and Low Service.*—The greater part of Washington was supplied with water from the Georgetown and Washington City Reservoirs by gravity up to the time when the filters were put in service. The pressures obtained in this way were less than usually considered desirable in modern cities. Most of the buildings in Washington, however, are comparatively low, and, with ample pipe capacities, a reasonable supply for fire-engines and for domestic purposes has been maintained.

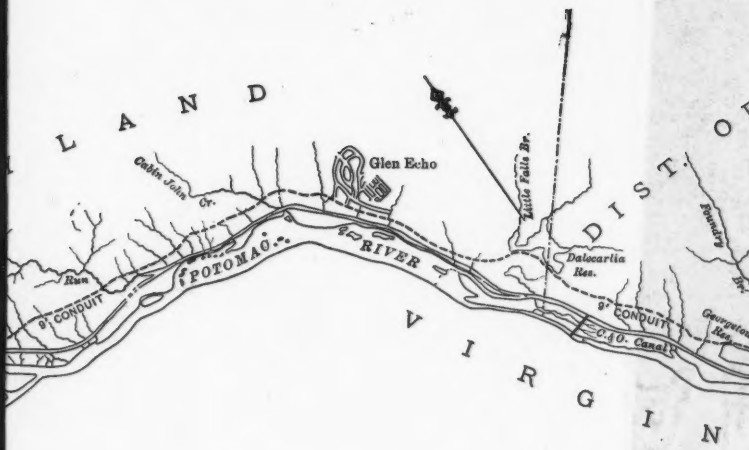
The higher portions of the city are supplied from two high-service reservoirs. Water is pumped to these from the low-service pipes. A pumping station in U Street was used for this purpose for many years, and has recently been superseded by the new and




# PLAN AND PROFILE OF WASHINGTON AQUEDUCT.

## SHOWING LOCATION OF SETTLING RESERVOIRS AND FILTERS.






# PLAN AND PROFILE OF WASHINGTON AQUEDU

## SHOWING LOCATION OF SETTLING RESERVOIRS AND FI

0 ½ 1 2 3 4

SCALE OF MILES

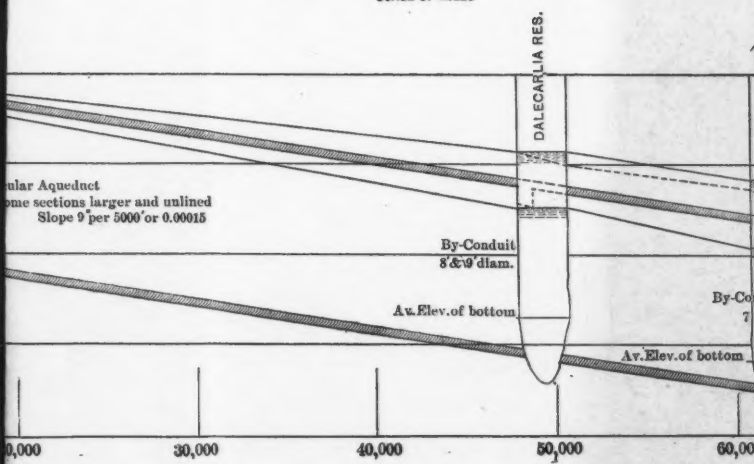
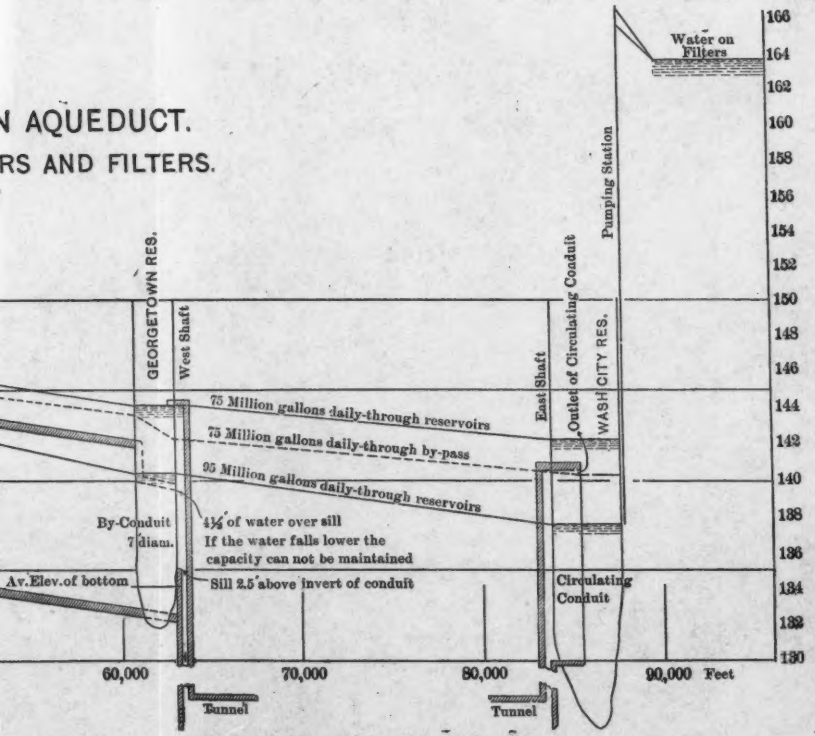


PLATE L.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1906.
HAZEN AND HARDY ON
WATER FILTRATION.




N AQUEDUCT.
RS AND FILTERS.



ample pumping station at Trumbull Street, near the Washington City Reservoir.

*Quality of the River Water.*—The Potomac River at Great Falls has a drainage area of approximately 11 043 sq. miles. The most important cities and towns upon its water-shed, with their populations for the last three censuses, and the rural populations, are given in Table 1.

TABLE 1.—POPULATION ON THE WATER-SHED OF THE POTOMAC RIVER.

Drainage area at Great Falls = 11 043 sq. miles.

| Place. | County. | State. | Approximate distance above Great Falls, in miles. | Population. | | |
|---|---|---|---|---|---|---|
| | | | | 1880. | 1890. | 1900. |
| Urban: Places of more than 4 000: | | | | | | |
| Frederick | Frederick | Md. | 45 | 8 659 | 8 193 | 9 296 |
| Hagerstown | Washington | Md. | 70 | 6 627 | 10 118 | 13 591 |
| Martinsburg | Berkeley | W. Va. | 75 | 6 335 | 7 226 | 7 564 |
| Waynesboro | Franklin | Pa. | 85 | 1 888 | 3 811 | 5 396 |
| Winchester | Frederick | Va. | 100 | 4 958 | 5 196 | 5 161 |
| Chambersburg | Franklin | Pa. | 115 | 6 877 | 7 863 | 8 864 |
| Cumberland | Allegheny | Md. | 155 | 16 693 | 12 729 | 17 128 |
| Frostburg | Allegheny | Md. | 165 | ..... | 3 804 | 5 274 |
| Staunton | Augusta | Va. | 175 | 6 664 | 6 975 | 7 289 |
| Total population, towns having more than 4 000 inhabitants | | | | 52 701 | 65 915 | 79 563 |
| Places having from 1 000 to 4 000 inhabitants | | | | 23 087 | 27 153 | 37 523 |
| Rural population (being all the remainder) | | | | 384 664 | 405 155 | 420 007 |
| Total population upon water-shed | | | | 460 452 | 498 223 | 537 093 |
| Population per square mile, places having more than 4 000 inhabitants in 1900 | | | | 4.7 | 5.9 | 7.2 |
| Places having from 1 000 to 4 000 inhabitants in 1900 | | | | 2.1 | 2.4 | 3.4 |
| Rural population per square mile | | | | 34.9 | 36.8 | 38.0 |
| Total population per square mile | | | | 41.7 | 45.1 | 48.6 |
| Increase in 10 years | | | | ..... | 8.1% | 7.7% |

The total population, and especially the urban population, is small in comparison with that upon many water-sheds used with filtration for public water supplies. The sewage pollution of the water, therefore, is not great in total amount, but the conditions seem to have been favorable for the transmission of infection, for

the typhoid rate in Washington has been high, and at times, at least, has followed the prevalence of the disease in the towns upon the water-shed.

The Potomac water is rather muddy. The amount of sediment carried by it, on an average, is many times greater than that carried by the rivers of New England and of the sandy glaciated regions of the Northern United States. On the other hand, the suspended matters are much less in amount than in most southern streams. Probably, on an average, they do not amount to more than one-fourth of the quantities carried by the Ohio River at Louisville, or to more than one-twelfth of those carried by the Missouri at its mouth above St. Louis.

The amount of suspended matter carried by the water fluctuates widely. There are periods, sometimes lasting for months, when the Potomac water is comparatively clear. At other times the water is excessively turbid, and at times very turbid water flows continuously in the river for a week or more. At these times the water may approach the condition of the Ohio and Missouri waters, although the duration of the turbid periods is less.

The muddiness of the Potomac water and its pollution by sewage, and consequently its disease-producing qualities, have alike contributed to its bad reputation and to a desire for an improved water supply.

*Investigations for Filtration.*—As early as 1894 the late Colonel George H. Elliott proposed the filtration of the Potomac River water by mechanical filters, and made a rough estimate of cost. In 1899 an appropriation of $3 000, afterward increased to $8 000, was made, to investigate experimentally the filtration of the Potomac water, and to cover the expense of making a report upon its advantages and cost.

Acting under this authority, the late Lieutenant-Colonel A. M. Miller, M. Am. Soc. C. E., then in charge of the Washington Aqueduct, organized and conducted a series of experiments with sand and mechanical filters, examined possible sites, and made preliminary plans and estimates of cost. In conducting these experiments Colonel Miller was assisted in the experimental work by R. S. Weston, Assoc. M. Am. Soc. C. E., while Mr. Hardy,

one of the writers, also investigated the possible locations for filters, and made preliminary designs and estimates of cost.

Colonel Miller's investigation was the first to determine accurately and adequately the character of the Potomac water with reference to the possibilities of its purification; and, among many other interesting results, served to demonstrate: first, that the water could not be filtered successfully by sand filters without the use of a coagulant; and second, that the water could be coagulated readily and successfully, and that when coagulated satisfactory effluents could be obtained from it with mechanical filters. Colonel Miller recommended the establishment of mechanical filters.

The matter being before Congress, a protest was made by the Medical Society of the District of Columbia. The doctors were opposed to the use of a coagulant, and believed that better and more certain results, particularly from a hygienic standpoint, could be obtained by the use of sand filters without coagulant. The contention of the Medical Society seemed to be irreconcilable with Colonel Miller's findings.

To obtain further information upon the points at issue, the Senate Committee on the District of Columbia, of which the late James McMillan was Chairman, gave a hearing in New York City, at which many persons interested or experienced in filtration were present, and were questioned as to the various matters.

Following this, the matter was referred by the Senate Committee to Rudolph Hering, George W. Fuller and Allen Hazen, Members, Am. Soc. C. E., for report as to the best method to be followed. This engineering committee had but a short time for its work, as Congress was about to adjourn, and immediate action was desired. The ground was canvassed by the committee rapidly, and a recommendation made that sand filters should be used, but that the Potomac water should receive a preliminary chemical treatment at those times when it was of such a character that after sedimentation alone it was incapable of yielding a satisfactory effluent. This recommendation thus met substantially the contentions of both parties. It was estimated from the records of the Washington Aqueduct that it would be necessary to treat the water in this way, on an average, about 30 days of the year, and that

during the remainder of the time the water could be filtered without such treatment.

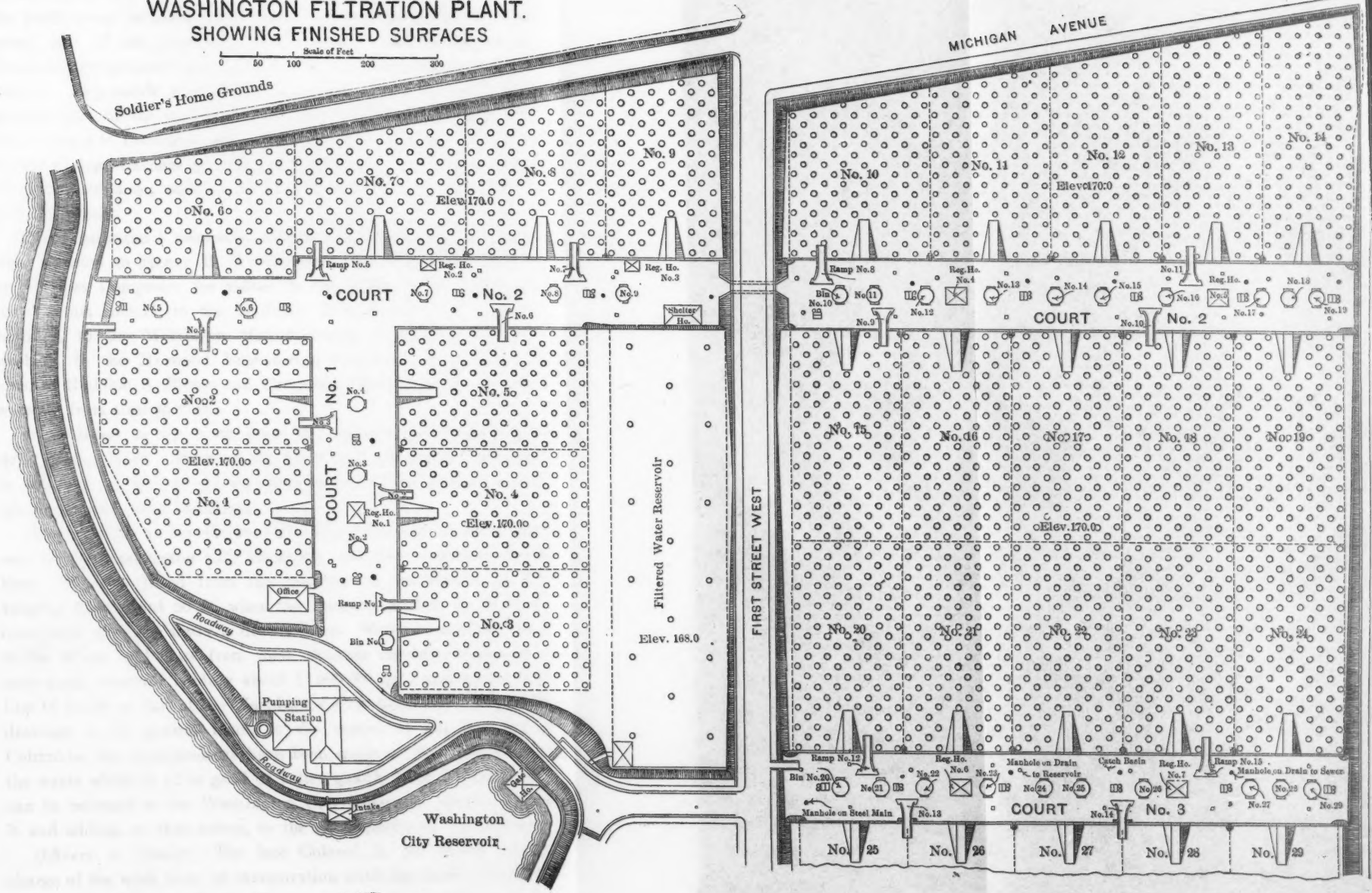
This recommendation was adopted by the Senate Committee, but, as the doctors still objected to the use of a coagulant, the appropriation was made for the construction of sand filters, without authority for its use. This was done with the understanding that the appliances for using a coagulant could be put in equally well at a later date, and that failure to authorize them at that time would not delay the introduction of filtered water.

*Selection of Site for Filters.*—After Congress had appropriated the money for the construction of sand filters, a Board, composed of Colonel Miller, Major Beach and Major Gaillard, was appointed by Brigadier-General John M. Wilson, Chief of Engineers, U. S. Army, to select a site. One site was considered near the line of the aqueduct and between it and the Potomac River, about 3 miles below Great Falls. A second site was considered near Brightwood Avenue, adjacent to and north of the Washington City Reservoir. The third site considered was between the Washington City Reservoir and North Capitol Street and between the Soldiers' Home Grounds and Cincinnati Street. This last site was selected. It was by far the most difficult and expensive site upon which to build, but it seemed to utilize more fully the existing plant, and was, moreover, in a central location.

*Preparation of Plans.*—Plans for filters upon this site were undertaken by Colonel Miller, assisted by Lieutenant (now Captain) George M. Hoffman, and by one of the writers, Mr. Hardy. Considerable progress was made, and a set of plans was prepared. Afterward, further consideration of certain matters led to the withdrawal of these plans, and the preparation of a revised set differing somewhat from the earlier ones. Both the writers were engaged upon these revised plans, under the direction of Colonel Miller, and assisted by Lieutenant (now Captain) W. P. Wooten, Assoc. M. Am. Soc. C. E., by R. D. Chase, Assoc. M. Am. Soc. C. E. (from Mr. Hazen's office), and by assistants in Colonel Miller's office.

*Contracts.*—Plans and specifications for the more important parts of the works were completed in December, 1902, and adopted; and proposals were received under them in January, 1903.

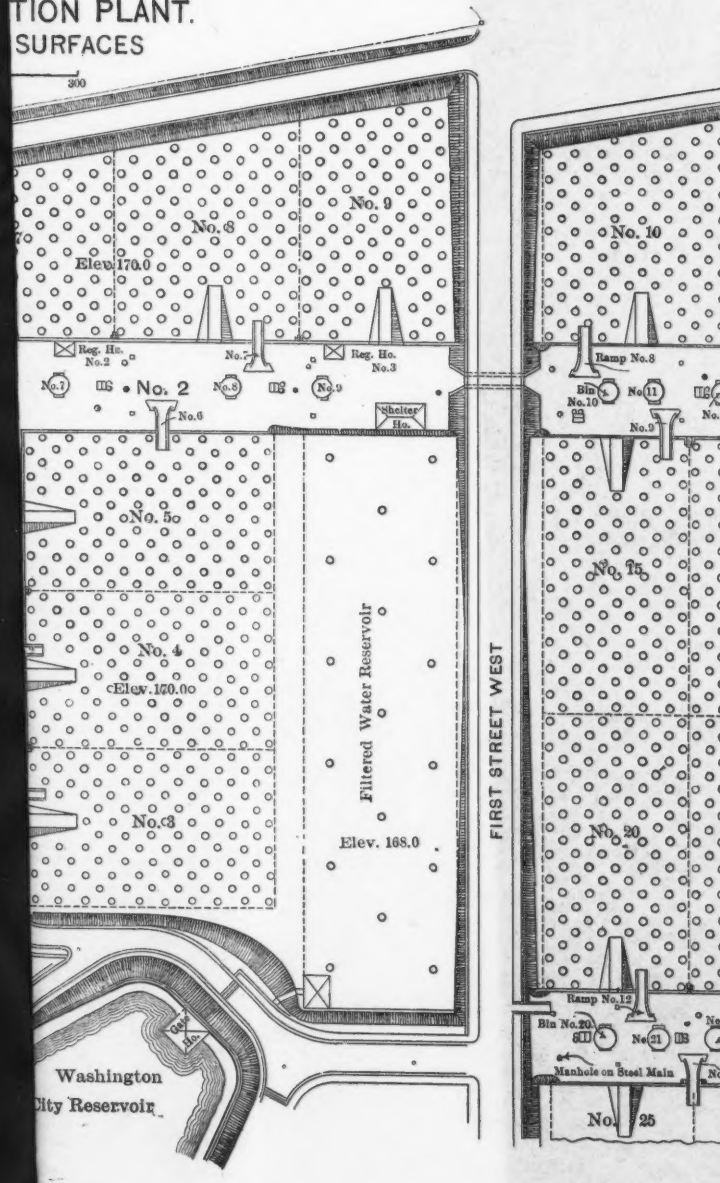
# GENERAL PLAN OF WASHINGTON FILTRATION PLANT. SHOWING FINISHED SURFACES

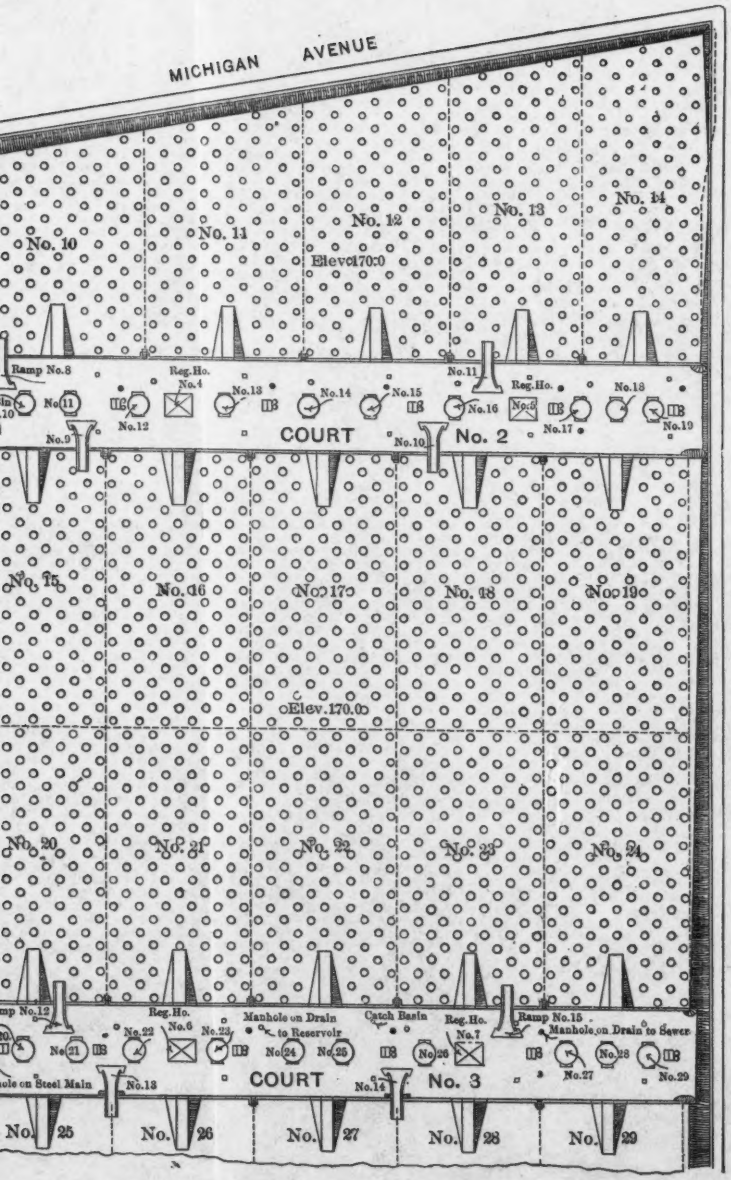


OF

TION PLANT.

SURFACES




MICHIGAN AVENUE
No. 10
No. 11
No. 12
No. 13
No. 14
Elev. 170.0
Ramp No. 8
Reg. Ho. No. 4
Reg. Ho. No. 5
No. 11
No. 12
No. 13
No. 14
No. 15
No. 16
No. 17
No. 18
No. 19
COURT
No. 2
No. 15
No. 16
No. 17
No. 18
No. 19
Elev. 170.0
No. 20
No. 21
No. 22
No. 23
No. 24
No. 25
No. 26
No. 27
No. 28
No. 29
Ramp No. 12
Reg. Ho. No. 6
Manhole on Drain to Reservoir
Catch Basin
Reg. Ho. No. 7
Ramp No. 15
Manhole on Drain to Sewer
Manhole on Steel Main
COURT
No. 3
NORTH CAPITOL STREET

The prices bid in these proposals somewhat exceeded those of the preliminary estimate upon which the appropriation had been based, and all the proposals were rejected. Shortly afterward, Congress appropriated an additional sum, and proposals were again invited. As a result, a contract for about one-half the work, comprising most of the masonry structures, earthwork, grading, etc., was awarded to Cowardin, Bradley, Clay and Company; a contract for the piping, drainage and some other parts, to the Brennan Construction Company; and a contract for the filter sand and gravel to L. E. Smoot.

Under subsequent proposals, contracts for pumping machinery were awarded to Henry R. Worthington; for boilers, to Babcock and Wilcox Company; for valves, to the Coffin Valve Company; for Venturi meters, to the Builders' Iron Foundry; for special castings, to the Wilkinson Manufacturing Company; for sand washers, to the Norwood Engineering Company; and for sand bins, to Rudolph S. Blome and Company. Many smaller contracts were let from time to time.

In addition to the work done by contract, considerable was done by day labor. Many of the concrete foundations were built in this way, as well as the regulator-houses, pumping-station, and laboratory and office buildings.

*General Plan of the Works.*—The filters are immediately adjacent to the Washington City Reservoir, and have a greater elevation. Water is lifted from the reservoir to the filters, the lift ranging from about 20 ft. when the reservoir is full, to 30 ft. or even more when the water is drawn down. Water is pumped direct to the filters, and flows from them through regulator-houses to a pure-water reservoir holding about 14 000 000 gal., and with a flow line 18 ft. above that of the Washington City Reservoir. The waste drainage is in general taken to the sewers of the District of Columbia, but arrangements have been made so that that part of the waste which is of as good or better quality than the raw water can be returned to the Washington City Reservoir, thereby saving it and adding, to that extent, to the net capacity of the aqueduct.

*Officers in Charge.*—The late Colonel A. M. Miller was in charge of the work from its inauguration until his death, September 18th, 1904. Captain W. P. Wooten was in direct charge of the

work under Colonel Miller's direction, and succeeded him temporarily. Colonel Smith S. Leach took charge of the work in November, 1904, Captain Wooten remaining in direct charge of the filter plant. On August 1st, 1905, Lieutenant-Colonel R. L. Hoxie, M. Am. Soc. C. E., succeeded Colonel Leach in charge of the work. Lieutenant E. J. Dent was assigned to the work, and succeeded Captain Wooten in direct charge of the filters on May 10th, 1905. Captain Spencer Cosby, M. Am. Soc. C. E., succeeded Colonel Hoxie in December, 1905, and is now in charge.

One of the writers, Mr. Hardy, as First Assistant Engineer, and afterward as Superintendent of Operation, has been connected with the work from its inauguration to the present time. The other writer, Mr. Hazen, was connected with the preliminary investigation, above mentioned, and with the preparation of plans and other matters connected with it, as Consulting Engineer, for nearly the whole period.

## Description of Work.

The construction of the work is in general shown by the plans and photographs which accompany this paper.

*Masonry.*—All the masonry structures are of concrete, and the general design follows closely the lines of the Albany filters.*

The floors are of inverted, groined arches, carrying piers with a slight batter near the bottom. The walls are of concrete, built in sections not exceeding 30 ft. long, the joints being tongued and grooved. The roof is of elliptical, groined arches, much like those at Albany, but with a deeper cut over the piers, so that the average thickness of the roof is only 0.61 ft., a saving of 14%, as compared with Albany.

The tongued and grooved joints in the walls were made by fastening a plank to the forms for the ends of the wall blocks first built. This formed a groove. The tongue was formed when the second block was built. Generally, the tongues had a slight batter and were at least three times as wide as long, to prevent them from breaking off when movements occurred.

Parapet walls were built over the outside walls along the courts, in order to save space. Generally, it is better to cover all the masonry with embankments, but in this case the site was so limited

* *Transactions*, Am. Soc. C. E., Vol. XLIII, p 244.

TYPICAL FILTER
SECTIONAL PLAN AND ELEVATIONS

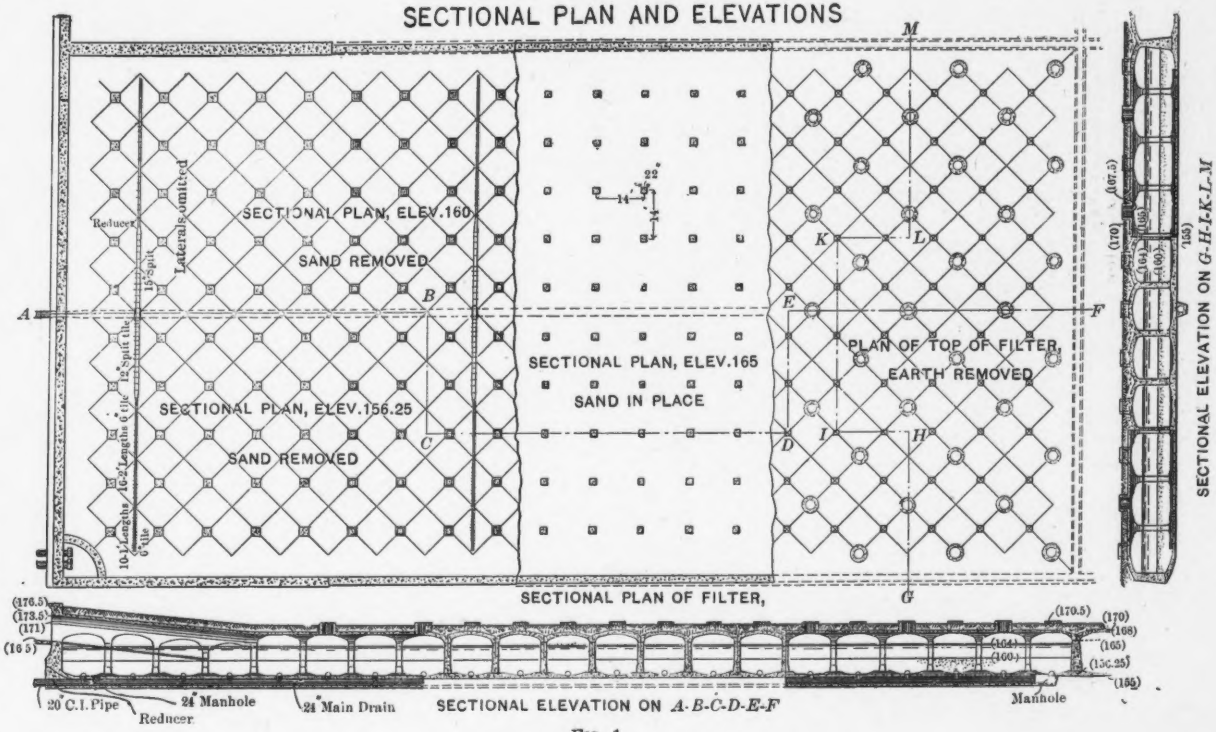



FIG. 1.

in area that the space which could be saved had a value more than equal to the concrete in the parapet walls, and in the extra thickness of the walls below, which was necessary in connection with it.

Generally, the outside wall acts simply as a beam bearing against the floor blocks and the roof blocks, and holding the earth pressure. The embankments beyond the walls serve to support them and to take the thrust of the vaulting (amounting to 4 000 lb. per lin. ft.), as well as the pressure from the filtering materials and the water inside the filters.

In some cases, owing to the limited space, it was not possible to build embankments thick enough to take these pressures safely, and at these points the thickness of the concrete was increased. It was increased a little where the embankment fell only somewhat below the standard, and much more where the embankment was more deeply cut. In a few cases the concrete was made so thick as to be substantially stable without earth backing, and the embankment was cut until it barely sufficed to cover the masonry.

In places where the tops of the filters are lower than the levels of the adjacent street, the building lines of the filters were put well up to the street lines, so that the embankments required for the street extended somewhat over the tops of the filters. At one place, where the street is much higher than the filters, the fill over the filters was considerably increased; and in this case a number of ventilator manholes were omitted, and the dimensions of the piers and vaulting were increased to carry the additional load safely.

*Settlement of Masonry Structures.*—An interesting feature of the masonry work was caused by the settlement of parts of the work. The highest part of the site was 65 ft. vertically above the lowest part. This was all graded to allow the filters to be at the same level. The maximum depth of cut was 35 ft., and the maximum height of fill 30 ft. Approximately, 5 acres of masonry structures were built upon fill. The filling was made with material obtained in the excavation, which was generally gravel mixed with clay. The material was excellent, and it would have been difficult to secure anything better for the purpose. It was placed in thin layers, and rolled thoroughly with heavy, grooved, steam rollers. Embankment built in this way was harder, as tested by the distance that an iron bar would penetrate, than the natural undisturbed

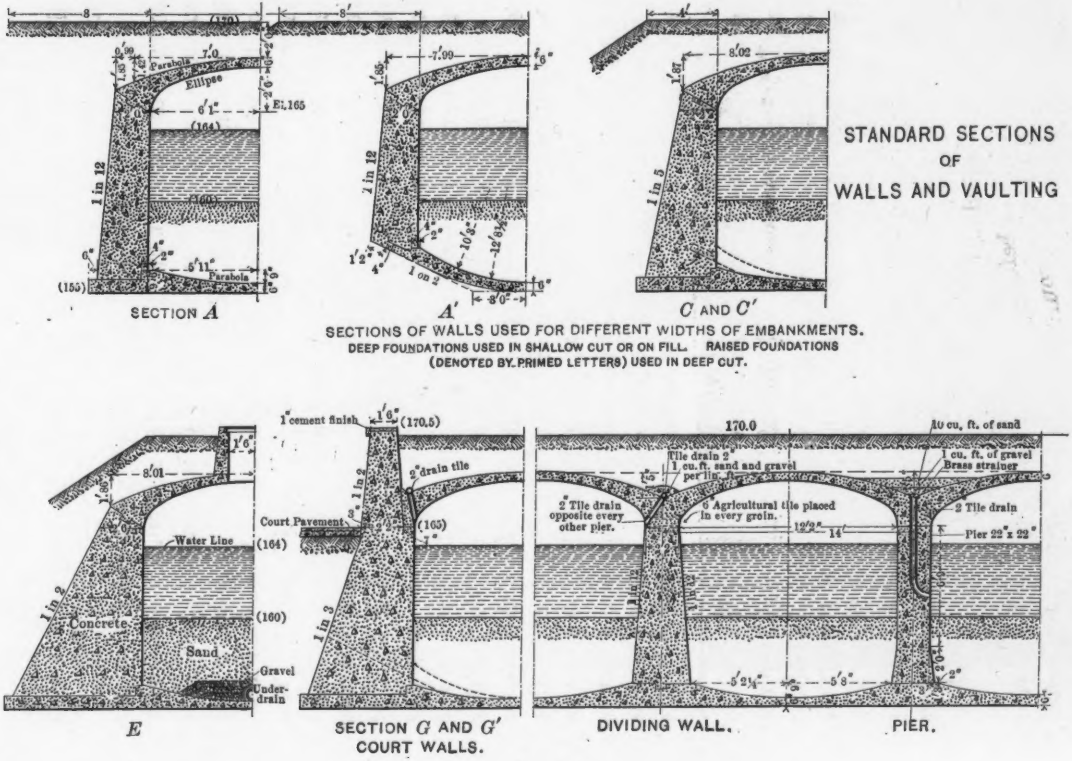

STANDARD SECTIONS
OF
WALLS AND VAULTING
SECTION A
A'
C AND C'
SECTIONS OF WALLS USED FOR DIFFERENT WIDTHS OF EMBANKMENTS.
DEEP FOUNDATIONS USED IN SHALLOW CUT OR ON FILL. RAISED FOUNDATIONS
(DENOTED BY PRIMED LETTERS) USED IN DEEP CUT.
Water Line
Concrete
Sand
Gravel
Under-drain
Court Pavement
1 cement finish
2" drain tile
E
SECTION G AND G'
COURT WALLS.
Tile drain 2"
1 cu. ft. sand and gravel
per lin. ft.
2 Tile drain
opposite every
other pier.
6 Agricultural tile placed
in every groin.
10 cu. ft. of sand
1 cu. ft. of gravel
Brass strainer
2 Tile drain
Pier 22" x 22"
DIVIDING WALL.
PIER.

FIG. 2.

material below the frost line, and seemed to be, in every way, as capable of carrying the loads to be placed upon it.

Notwithstanding this, the masonry, wherever it was built upon fill, settled more or less. As a maximum, the settlement reached about 6 in.

The most serious break caused by settlement occurred at the entrance of Filter No. 27. One side of this entrance was on undisturbed material. The natural slope of the ground at this place had been steep. A short distance to one side, the masonry was constructed on a deep deposit of fill, most of which had been made prior to the acquirement of the property by the Government. This material seemed to be solid, but there must have been a soft layer beneath, for a settlement of 6 in. took place in one part of it, and this maximum settlement was within a distance of about 50 ft. of undisturbed material which did not settle at all. The inequality of settlement was too great for the masonry to adapt itself to, and a number of large cracks opened and one section of the vaulting fell. This happened shortly after the filter was filled with water for the first time. The settlement took place rapidly, and, as in other cases, seemed to come to a definite end in a short time. One section of the vaulting and four piers were rebuilt. The replaced section of vaulting was in the inclined entrance, and the general weakness of the structure at this point, as will be mentioned further, was a contributing cause to the unusual damage sustained. In a few other cases cracks in the masonry were produced by this settlement. Generally, however, the movement only caused openings of the tongued and grooved joints of the wall blocks, and slight readjustments of the floor and vaulting blocks. A few of the largest cracks were grouted. Smaller ones were caulked with oakum, which had the advantage of leaving them so that a further movement would produce no damage to the concrete. The openings between the floor and vaulting blocks were seldom large enough to permit of caulking, and nothing was done to them.

The greatest settlements were where the grading, with reference to the use of the land for building purposes, had been done before the property was purchased by the Government. Some of this grading had been done years before. The fills made in this way were in general excavated, in the course of the work, to the original

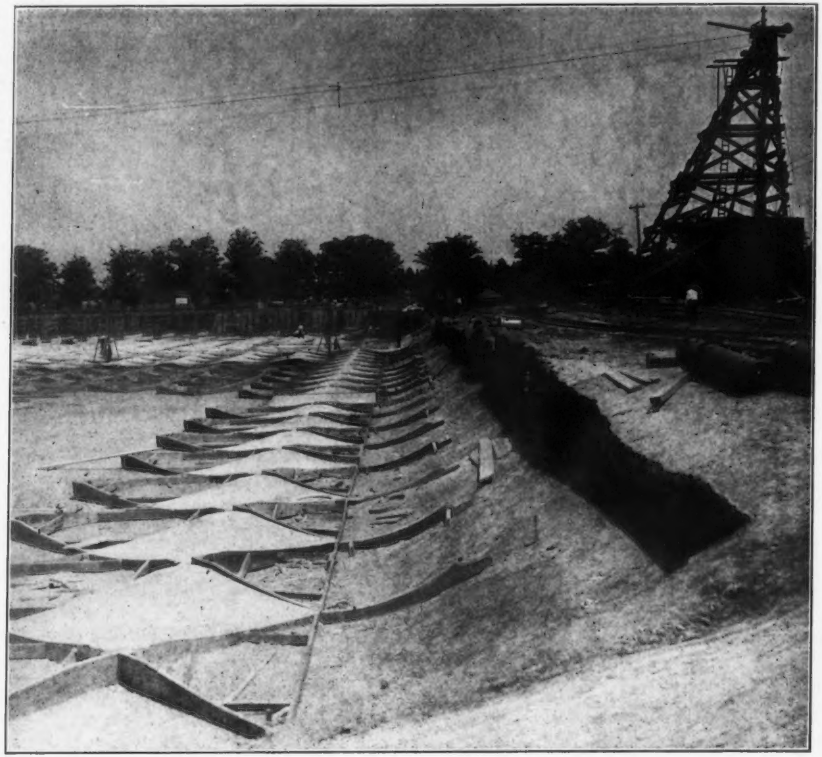


FIG. 1.—FLOOR BLOCKS AND INVERTED GROINED ARCHES.



FIG. 2.—INTERIOR, FILTERED WATER RESERVOIR.

surface, and refilled with embankments made as above described, before the masonry was placed, but in some cases it was difficult to tell just where the old surface had been. In other places where it had been under heavy loading in deep fill, it seemed to be as solid and as little likely to settle as the original material, and such places were left intentionally, as it was believed that they were sufficiently solid to carry the loads to be placed upon them.

It is difficult, or rather impossible, to determine from the old records just how much of this old filling was left in place. It is known that there was considerable of it, and the greatest settlement seems to have occurred over those places where it was deepest.

In some places the filters were built 1 or 2 in. higher than the intended grade, so as to approximate more nearly the desired conditions after settlement. The settlement of the masonry does not in any way affect the stability or usefulness of the plant. The greatest practical inconvenience comes from the differences in level of the filters resulting from it.

*Cracks in Entrances.*—Each filter is provided with an inclined entrance. Such entrances have been used in other covered filters, and are designed to facilitate carrying sand in and out. With the system of sand handling adopted at Washington, they will not ordinarily be used for that purpose. They simply serve as a reserve which can be used in case the sand-handling apparatus fails to perform its work.

The line of travel in these entrances passes necessarily through the plane of the vaulting, and the vaulting is raised over them. The concrete structures built at this point are larger and heavier than the normal vaulting, and are intended to be strong enough to meet the extra strains which occur at this point. In the Albany filters, where substantially the same design was used for this part of the work, this result was accomplished. In Washington, with a much greater extent of vaulting, there were expansions and contractions of greater magnitude than occurred at Albany, and in some cases settlements of the foundation were also a factor. The entrances were forced to act to some extent as expansion joints, particularly in parts of the work where the concrete was placed late in the fall when the temperature was low. In those places there were movements in the vaulting, with the higher temperature in the follow-

ing summer, which cracked the concrete at the entrances. The movements were such as to break several piers, and it was necessary to replace them. The cracks for the most part were capable of being grouted and repaired, but it is clear that the design of entrances, in works where the vaulting is uninterrupted and extensive, should be modified.

*Diagonal Vaulting.*—At several places the shape of the site was such that it was necessary to place the outside walls on lines not parallel with the pier lines. This involved complications in the construction of the floors and vaulting. The plan adopted was to place the outside wall on a diagonal line and to carry a cylindrical arch of the usual shape springing from it for a distance not exceeding one-half the usual span of the arch. The piers were built on the usual plan, as near the wall as possible, and the groined-arch vaulting was carried up from them. The customary curves were used in all cases, and the various surfaces intersected formed irregular arches which tended to be narrow and pointed like Norman arches. This became well developed at places where the piers were near the walls. The angles of the outside walls were arranged so that the relations of the piers to the walls became the same at regular intervals, and this allowed the special centering to be used over again. In some cases there were small triangular places at the tops between the different surfaces, which were not large enough to warrant the construction of another pier. These were built perfectly flat, a small quantity of steel being used in the concrete.

The piers are all at 14-ft. centers, except that the span was made 4 in. shorter for five of the filters, in order to fit the dimensions of that part of the site with a fairly regular design.

In the pure-water reservoir the piers are 18 ft. apart on centers. This greater span was adopted to avoid the use of piers too high for their width. The height of these piers is about 25 ft., or about ten times their width.

The floor of the pure-water reservoir is not level. Part of the site was naturally at, or had been excavated to, a level below that at which water could ordinarily be used from it. It was cheaper to carry the floor of the reservoirs at the level of this material than to fill it and build a shallower reservoir, and in emergencies the water stored in this lower part of the reservoir would be of value.

PLAN AND SECTIONS OF
FILTERED WATER RESERVOIR.

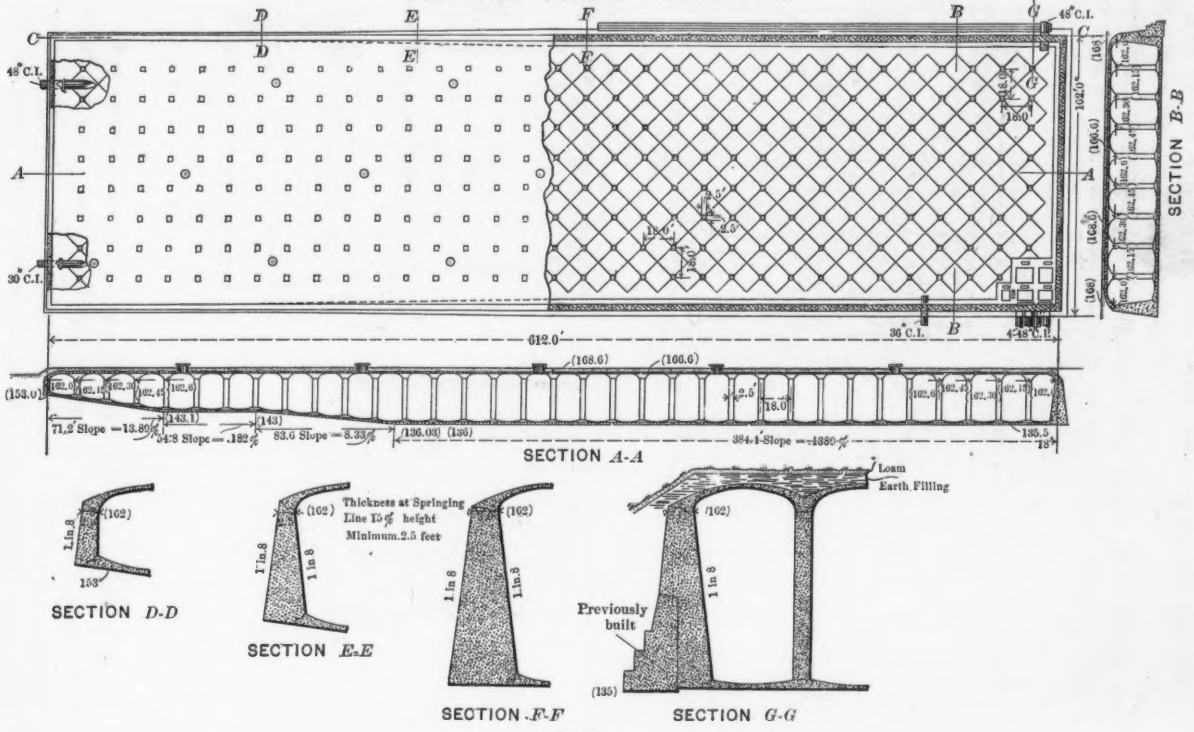



FIG. 3.

It was not worth while excavating the remainder of the site to this depth, and consequently a sloping floor was used, thereby largely reducing the quantities of excavation, and of masonry in the outside walls, without materially reducing the effective storage capac-

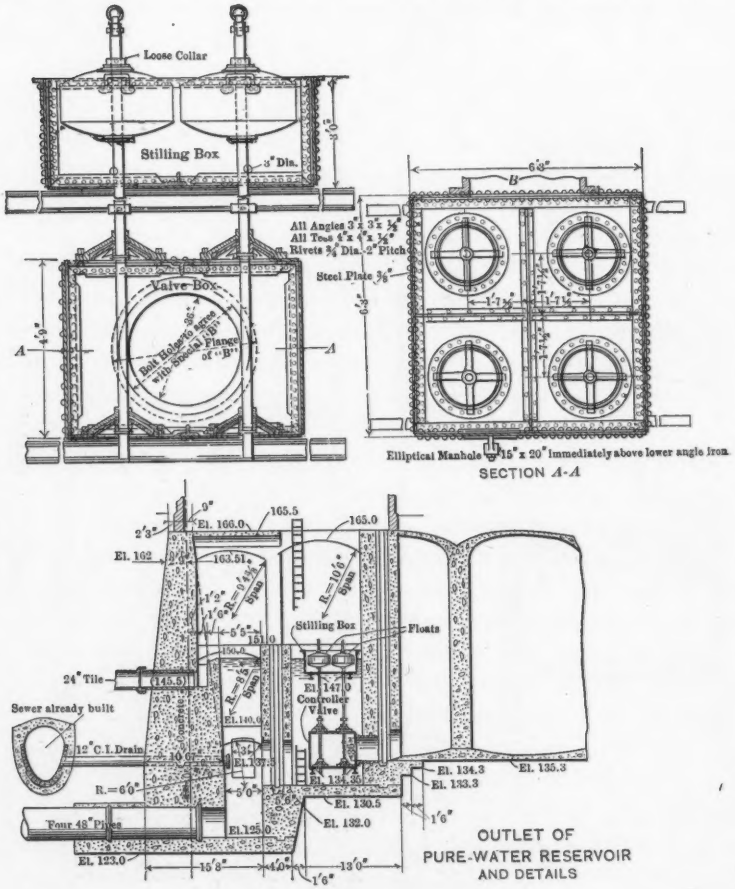
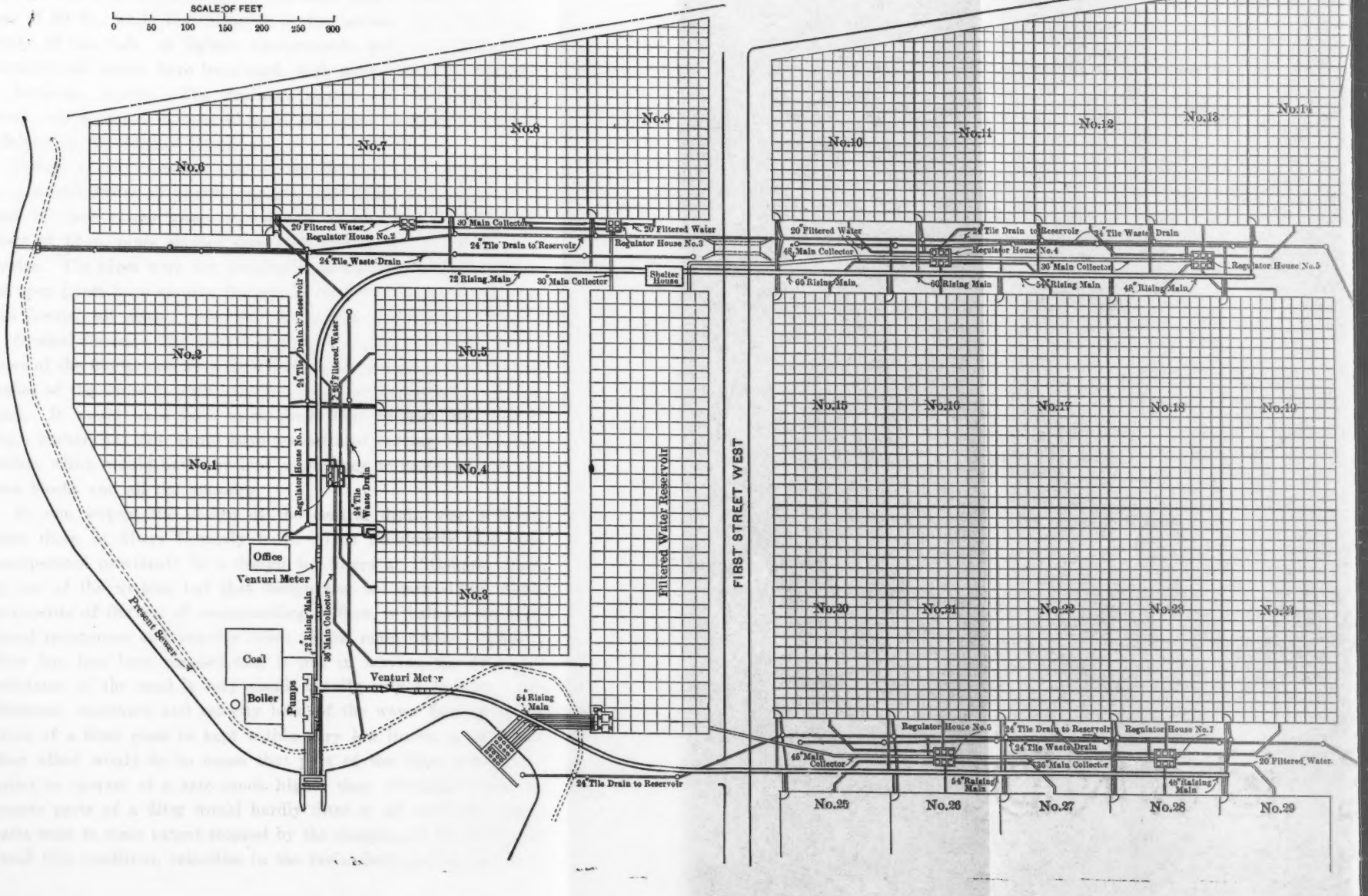



FIG. 4.

ity. The sloping floor was built in the usual way, by simply raising the grades and setting the forms on a slope, strips being nailed to the tops on the lower side to level up for the piers.

The outside walls of the pure-water reservoir are like the filter walls, but much heavier on account of their greater height and the

GENERAL PLAN OF
WASHINGTON, FILTRATION PLANT.
SHOWING MAIN PIPE LINES.



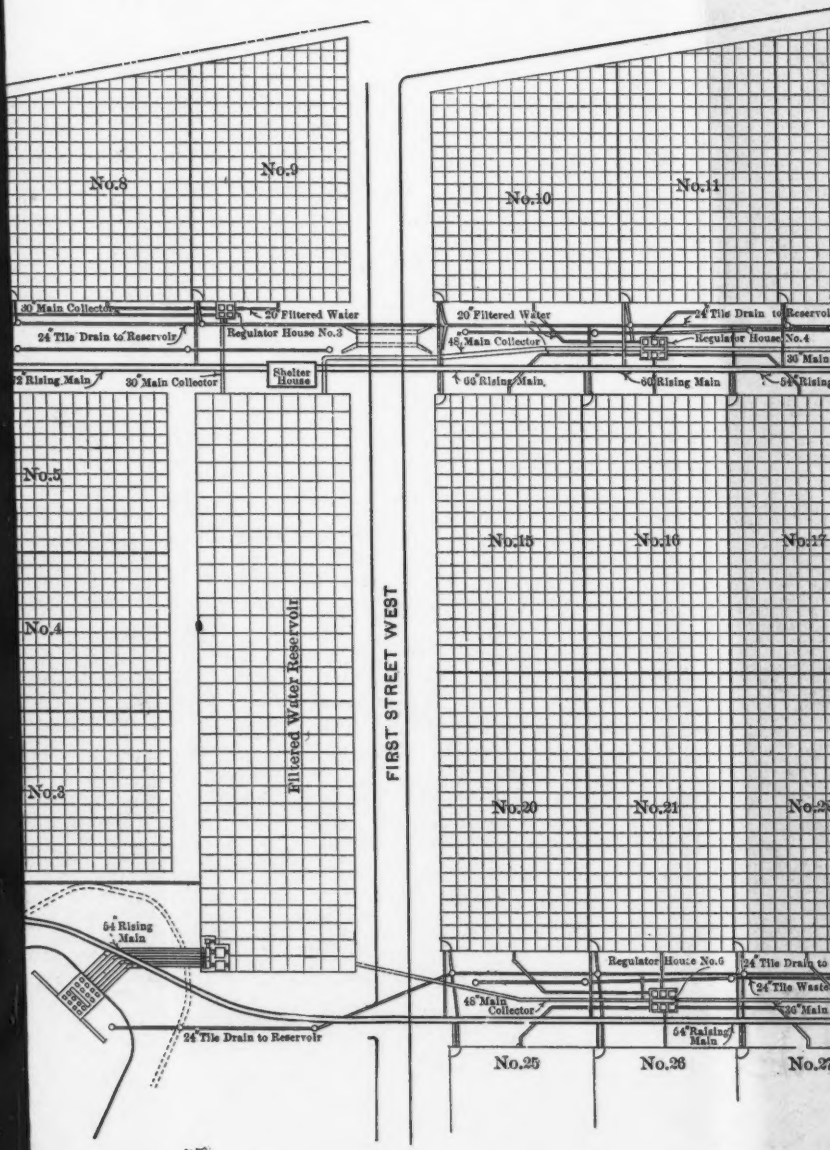
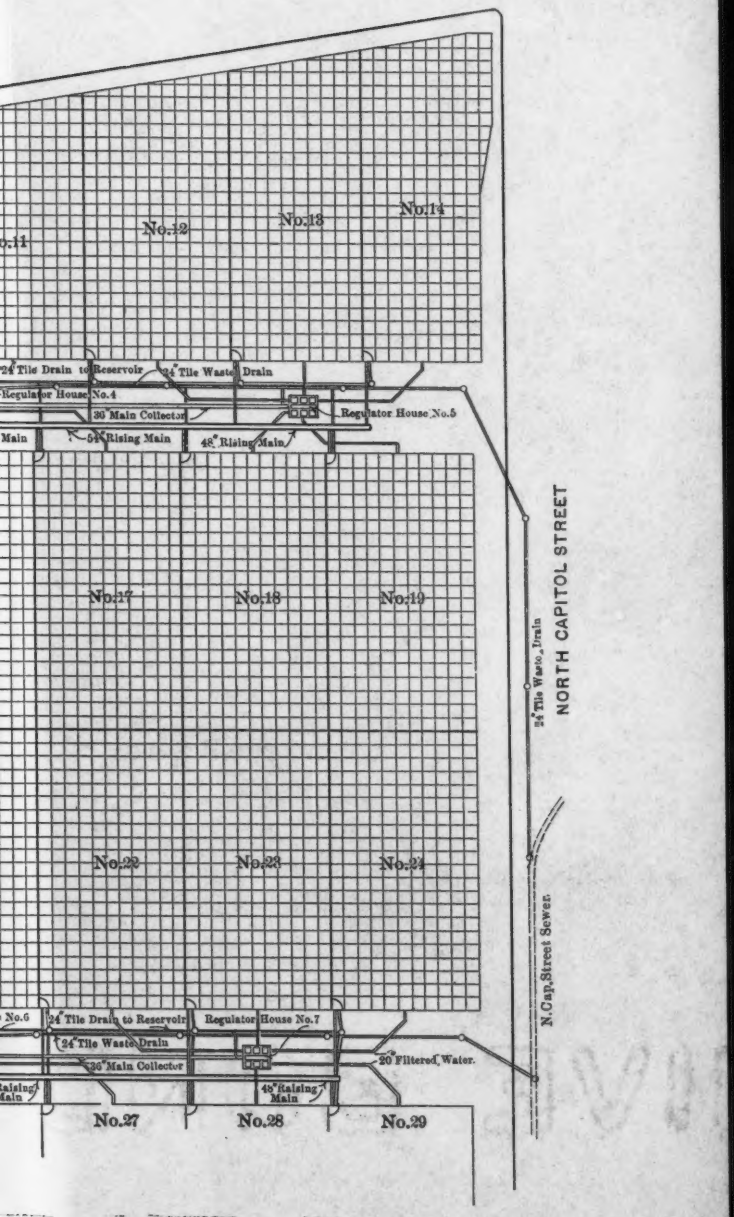

No.8
No.9
No.10
No.11
30" Main Collector
24" Tile Drain to Reservoir
20" Filtered Water
Regulator House No.3
Shelter House
30" Main Collector
20" Filtered Water
48" Main Collector
24" Tile Drain to Reservoir
Regulator House No.4
66" Rising Main
60" Rising Main
No.5
No.4
No.3
Filtered Water Reservoir
FIRST STREET WEST
No.15
No.16
No.17
No.20
No.21
54" Rising Main
Regulator House No.6
24" Tile Drain to
48" Main Collector
24" Tile Waste
24" Tile Drain to Reservoir
54" Raising Main
No.25
No.26

PLATE LIII.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1906.
HAZEN AND HARDY ON
WATER FILTRATION.



greater thrust of the arches. The section was varied according to the height of the wall in such a way that the thickness of the springing line was 15% of the height of the wall, with a minimum thickness of 30 in., while the thickness at the bottom was 40% of the height of the wall. A lighter steel-concrete wall, or a buttressed concrete wall might have been used, with some saving in expense.

*Drainage System.*—The drainage system of the Washington filters was designed in general upon the same principles as those followed in the Albany filters.

Owing to the increased size of the filters it was necessary to have lateral drains of greater capacity, and split 12-in. pipes were used in those places where round 6-in. pipes were not sufficient. Tests of 12-in. pipes showed that they were amply strong for the service. The pipes were not perforated, as at Philadelphia, because the open joints have an area far greater than the area of the drains, and furnish all needed space for the entrance of water.

*Central Drains.*—The central drains, as at Albany, are below the floors of the filters, and were built first. This permitted the inverted arches of the floors to pass over them without interruption of any kind. It would have been more convenient to have the central drain higher, but this would have necessitated cutting the inverted arches, which would have involved a tendency to movement by the floor blocks and all the masonry.

In one respect the design of the central drain was different from those in filters formerly built. This peculiarity had been incorporated previously in a design for filters at Pittsburg, made by one of the writers, but that design was not carried out there. It consists of the use of compensating orifices, to balance the frictional resistances and velocity heads in the main drains. When a filter has just been cleaned and is put in service, the frictional resistance of the sand is very small, usually only 1 or 2 in. The frictional resistance and velocity head of the water flowing in the drain of a filter must be kept within very low limits, as otherwise their effect would be to cause that part of the filter nearest the outlet to operate at a rate much higher than intended; while the remote parts of a filter would hardly filter at all until the nearer parts were to some extent stopped by the clogging of the sand. To avoid this condition, velocities in the main drain as low as 0.6 ft.

per sec., or less, are necessary, and this results in a very large central drain for filters as large as those at Washington. The total loss of head in these drains is not serious, from the standpoint of the level of the water delivered; but its disturbing effect upon the equality of the rate of filtration is a most important matter.

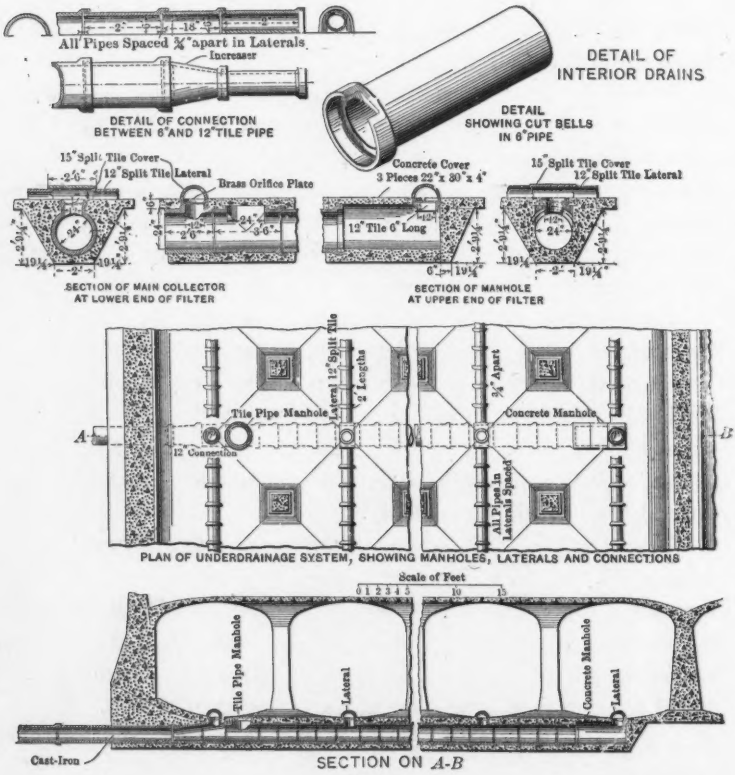



FIG. 5.

The principle of the compensating orifice is to introduce resistances, at each point where laterals enter the main drain, equal to the combined frictional resistance and velocity head in the main drain from the most remote point to the point in question. If the computations are correctly made, this would result in making the resistance from any point back of a compensating orifice, through

it, and thence to the outlet, precisely the same as from any and all other similar points. The result should be to draw water at exactly the same rate of filtration from each section of the filter. As all the losses in the underdrains and compensating orifices change with the changes in rate in nearly the same ratio, namely, as the square of the rate of filtration, it follows that a compensation adjusted for one rate of filtration is substantially right for any other rate. The fact that the loss of head in the sand varies directly as the rate, instead of as the square of the rate, does not enter into the comparison; for, at a given rate, this loss is the same for all parts of a filter, and therefore there is no tendency from it to produce unequal rates of filtration.

The compensating orifices were brass discs, with circular openings cut to the computed diameters and placed in the entrances to the main drains, all other parts of which were finished water-tight, or substantially so. By this construction the main drains were 24-in. tile pipe throughout, which is sufficient; but without the orifices it would have been necessary to use 36-in. pipe. The saving effected by the use of the orifices was roughly $500 per acre, or $14 500 for the plant.

*Gravel.*—The total depth of the gravel layer midway between the piers is 12 in., decreasing to 3 in. at the piers. Three grades of gravel were used. The material throughout was crushed stone, either trap or granite, limestone and material containing lime in large quantity being excluded. The lower layer of coarse gravel was 7 in. thick, coming just over the tops of the drains. The two finer layers were each 2½ in. thick. The gravel was kept 2 ft. away from the outside walls. The sizes and methods of placing were practically identical with those used at Albany.

*Sand.*—The sand is, in a way, the most important part of the filters. To secure the best sand that can be reasonably obtained is important. The specifications for sand were much like those used at Albany, but required a somewhat greater freedom from fine particles, as experience had indicated that this was necessary to secure the best results in the filtration of river waters containing as much clayey turbidity as the Potomac water. It was expected when the specifications were drawn that the sand dredged from the Potomac would be used. The specifications were general, and ad-

mitted any sand of the required quality without regard to its source. The contractor actually furnished sand from a bank at Laurel, Md., on the main line of the Baltimore and Ohio Railroad, half way to Baltimore. This bank was probably of Tertiary origin, and consisted of layers of clay and sand. The sand in the sand layers was of good quality, except that more or less clay was distributed through it. The layers of clay ranged in thickness from a few inches to several feet, and the mixing was such that it was not possible to take the sand without the clay.

The method of securing and preparing filter sand of the requisite cleanliness and of the quality specified was interesting and novel. The procedure was as follows: The sand was excavated from the bank with steam-shovels, taking the mixed material, to a depth often reaching 20 ft. The material obtained in this way consisted mostly of sand, but large and small lumps of clay were always mixed with it, and the top soil was not separated. The proportion of the material which could not form part of the filter sand was rather large. The sand was loaded on cars, which carried it on temporary tracks to the screening and washing plant built close to the main line of the Baltimore and Ohio Railroad.

The material was first dumped from the cars through a coarse grating which separated many of the largest lumps of clay. It then passed through a revolving screen, with holes about 2 in. in diameter, which removed further quantities of clay in lumps. It was then taken by a link-belt elevator to the top of a timber trestle, and discharged into a revolving screen, with round holes having a size of separation of about 4 mm. Water jets played upon this screen and facilitated the passage of sand through it, while much fine gravel and some additional lumps of clay were removed. The specifications provided that the sand must be free from particles more than 5 mm. in diameter, and the screen secured this result. The material passing through the screen consisted of the sand, together with a large quantity of clay, partly pulverized and partly in lumps, all carried by a considerable quantity of water. The mixture then passed to a series of pug-mills. The revolving arms in these broke up and pulverized the remaining clay lumps. This treatment was necessary for a material containing clay in lumps, but would be unnecessary for sand not containing such material.

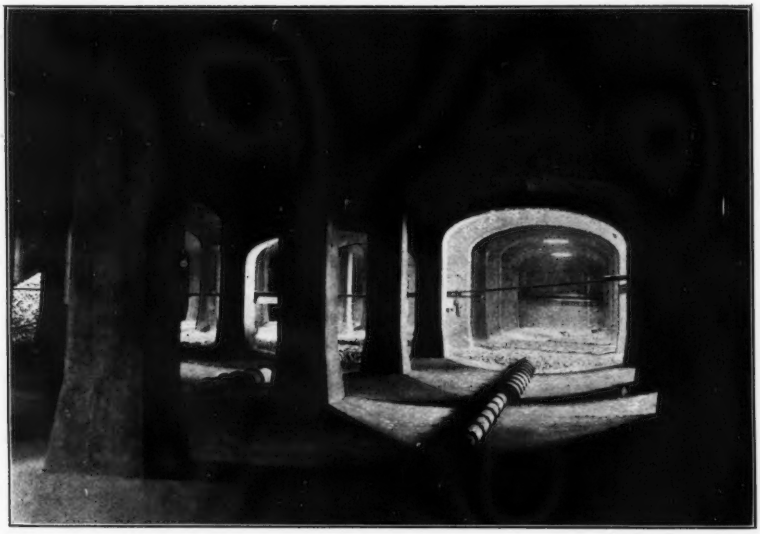


FIG. 1.—INTERIOR VIEW OF FINISHED MASONRY, SHOWING ARRANGEMENT OF LATERAL DRAINS AND GRAVEL LAYERS.

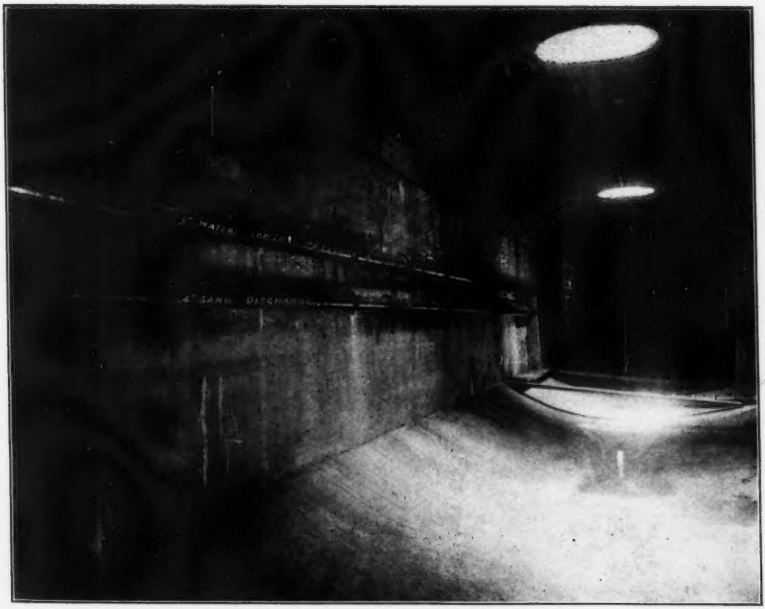


FIG. 2.—SAND PIPING IN A FILTER BEFORE PLACING FILTERING MATERIALS.

The pug-mills incidentally served to separate a portion of the clay from the sand, for an excess of water entered them, and extremely dirty water was constantly wasting over their tops, while the sand was drawn out from points near the bottoms in much the same way as it was subsequently drawn from the sand washers.

The mixture of sand, clay and water leaving the pug-mills next passed to the washers. These washers consisted of three long narrow boxes with bottoms having slopes of 1 in 6 to the point of discharge. The boxes were 16 ft. long, 24 in. wide and 18 in. deep at the upper end. There were four pipes, perforated for their entire length, in the bottom of each box, the holes opening directly downward. Water was forced through these pipes at a rate of about 1 cu. ft. per min. per sq. ft. of box area. This water went upward and overflowed into a trough running lengthwise of the box at the top. The mixed materials entered this box at the upper end, flowed through it, and were discharged at the lower end from the bottom. There were, therefore, two movements in each box: first, a movement of wash-water upward from the bottom of the box to the top and out through the waste overflow; and second, a forward movement of sand from one end of the box to the other. The upward movement of water, starting from the whole area of the bottom and overflowing from most of the area of the top, kept the sand in a semi-suspended state and practically in the condition of quicksand.

Under these conditions the larger particles of sand rapidly sank to the bottom while the finer particles were carried to the top. The sand at the bottom was in contact with the clean water as it first entered the box, while, by controlling the quantities of sand let in and drawn out, the finer particles could be forced to the top and out through the waste overflow to any desired extent. The level of the sand in the box was usually carried not more than about 6 in. below the surface of the water.

As the sand in the box was in the state of quicksand, it was possible to draw it out, through a gate placed just above the bottom at the lower end of the washer, in the form of a fluid containing very little water. Generally, 10 parts of the mixture drawn from the outlet contained 9 parts of solid sand. The mixture fell into a large hopper, from which a gate allowed it to flow from time to time into cars on a side-track below, often without further separation of

water, except as it gradually drained out through the cracks in the hopper and in the bottoms of the cars.

In general, it was found that 1 cu. yd. of sand per hr. could be washed for each square foot of box area, and sometimes a larger quantity was passed.

A washing box of this character was first designed by one of the writers for use in preparing filter sand at Yonkers, N. Y.* The same type of box was used in preparing all the sand placed in the filters at Providence, R. I., and has also been used elsewhere.

The separation of the clay from the sand in such large quantities and so cheaply was an achievement which would hardly have been regarded as possible at the time the contract for filter sand was made, and the use of this process cheapened the sand washing very greatly, the actual cost to the contractor being far below the contract price.

Although exact figures are not at hand, it appears that the volume of water used in washing the sand was not more than five or six times that of the sand. The wash-water was obtained from a small creek nearby, and was pumped through a 10-in. pipe. After rains the water in this creek was quite turbid, but this turbidity did not interfere materially with the washing, or with the quality of the sand produced.

In a working day of 10 hr. more than 900 cu. yd. of filter sand were frequently produced, and, had it been possible to handle the sand at the filters more rapidly, the plant could have worked at night, with a greatly increased output.

The specifications provided that the filtering sand should be entirely free from clay. This specification had proved sufficient in securing sand from river deposits and from sand banks of glacial origin. It did not prove satisfactory in the case of this sand, as the raw material contained large quantities of clay. The clay stuck to the particles of sand on drying, and the ordinary mechanical analysis, by sifting the material in a dry state, was inadequate to show its presence or amount.

It becomes apparent at once that a method of measuring the amount of clay in the sand must be found and used, and definite

* Described in *Engineering News*, July 14th, 1904, and in *The Engineering Record* July 2d, 1904.

SKETCH OF
SAND WASHER BOX
USED BY CONTRACTOR
AT WASHINGTON, 1904.

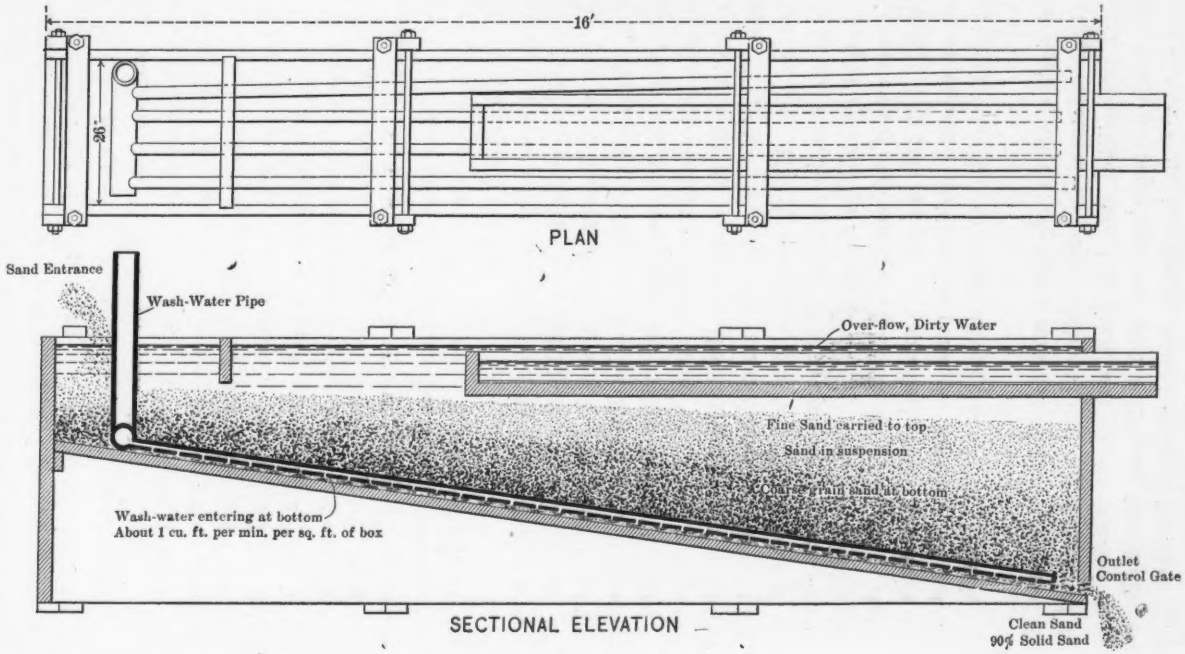



FIG. 6.

limits set to the amount of clay that could be present, which should be substantially equivalent to the requirements of the specifications.

The method adopted of determining the amount of clay was as follows: A weighed quantity of sand, usually 25 g.—but less if there was considerable clay in it, and more if there was but little—was agitated for some minutes with several times its volume of water. The sand for this purpose was taken directly from the washers, and was not dried, as drying increased the difficulty of getting the clay into suspension. If the sand had dried before testing, it was necessary to keep it moist and agitate it for some time to get all the clay loose. When this was accomplished the mixture was made up to a volume of 1 liter in a graduated glass. This was allowed to stand for 1 min. The turbidity of the supernatant fluid was then taken by observing the depth below the surface that a platinum wire could be seen, by the method of the United States Geological Survey.

These observations were taken in the graduated glass for convenience. This was not strictly in accordance with the official instructions, but it was more convenient, and the comparative results were good. Jackson's turbidimeter was used with good results for night work, but the rod was preferred by the inspectors when it could be used. The turbidity of the water thus found was multiplied by the ratio of the volume of the mixture to the weight of sand taken. That is to say, for the quantities above stated it was multiplied by 40. The figures thus represent approximately the turbidity in the sand in parts per million by weight. One part of clay by weight actually produces about two parts of turbidty, because the particles of clay are much finer than the particles of standard turbidity, but this matter is overlooked, and the results are expressed as standard turbidity in parts per million. To get the actual weight of the clay, therefore, the figures should be divided by two.

It was decided after study that a reasonable interpretation of the specification, expressed in terms of turbidity, was represented by 4 000 parts per million, and this limit was rigidly insisted upon. Generally, the sand contained less than 3 000 and frequently less than 2 000 turbidity, the last figure corresponding to less than 0.1% of actual clay by weight in the sand as delivered. That this result

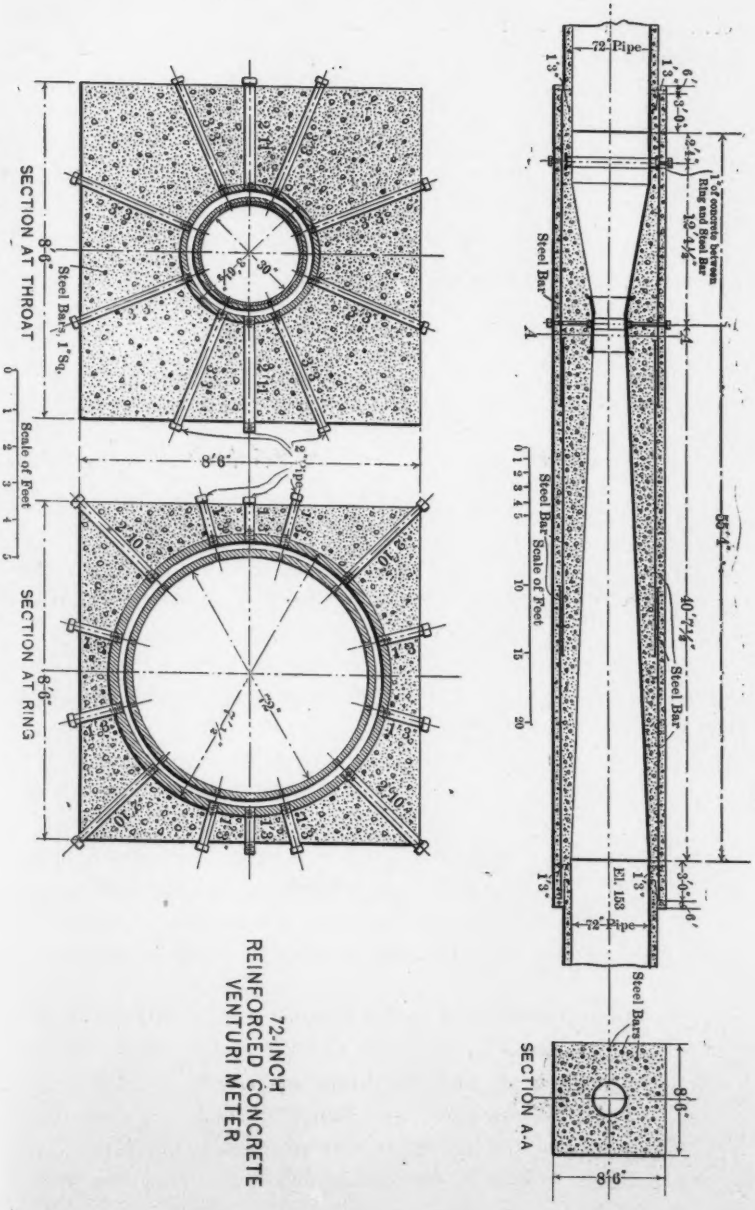

72-Pipe
Steel Bar
Steel Bar
Steel Bar
Steel Bars
Scale of Feet
SECTION AT THROAT
SECTION AT RING
SECTION A-A
72-INCH
REINFORCED CONCRETE
VENTURI METER

FIG. 7.

could be regularly secured from a bank where a considerable percentage of the total material was clay is, the writers think, a very remarkable result, indicating both an excellent apparatus and most efficient management, on the part of the contractor, and by the sand inspectors.

Part of the sand-washing plant was duplicated. This was done before the full capacity of the part first built was realized. It was intended to insure against delay in case of accident and to allow an increased output, but the first part did so well that the second part was used hardly enough to test it.

The sand was taken in cars to an elevated siding near the filters, and dumped into hoppers. These hoppers were provided with sand-gates, and carts were driven underneath and loaded from them. These carts were taken over the roofs of the filters, and the sand was dumped through the manholes. Chutes were arranged under the manholes, upon which the sand fell. This broke the force of the fall which, otherwise, might have compacted the sand to an undesirable extent, and also threw it to a considerable distance horizontally. The chutes were revolved, and in this way most of the filter sand was placed directly where it was wanted without further handling. It was necessary to place only a small part of it with shovels.

This method of placing the sand in the filters is so simple and cheap that it has been adopted for regular use in replacing the washed sand in the filters.

The sand settled, on an average, about 5% when it was wet and the filters were placed in service. The average depth of the sand in the filters after settling was 38 in., but different filters were filled to different depths, so that when sand is replaced from the washers in the filters it will go first to the filters having initially the least sand, and a regular regime is thus established from the start.

*Piping.*—All the piping for taking the filtered water to the pure-water reservoir is of cast iron, 48 in. in diameter, or less. The main pipes for carrying the raw water from the pumps to the filters are of riveted steel. Two lines were provided, one 72 in. in diameter, supplying 19 filters; and one 54 in. in diameter, supplying 10 filters. These pipes are coated with asphalt and entirely surrounded by concrete.

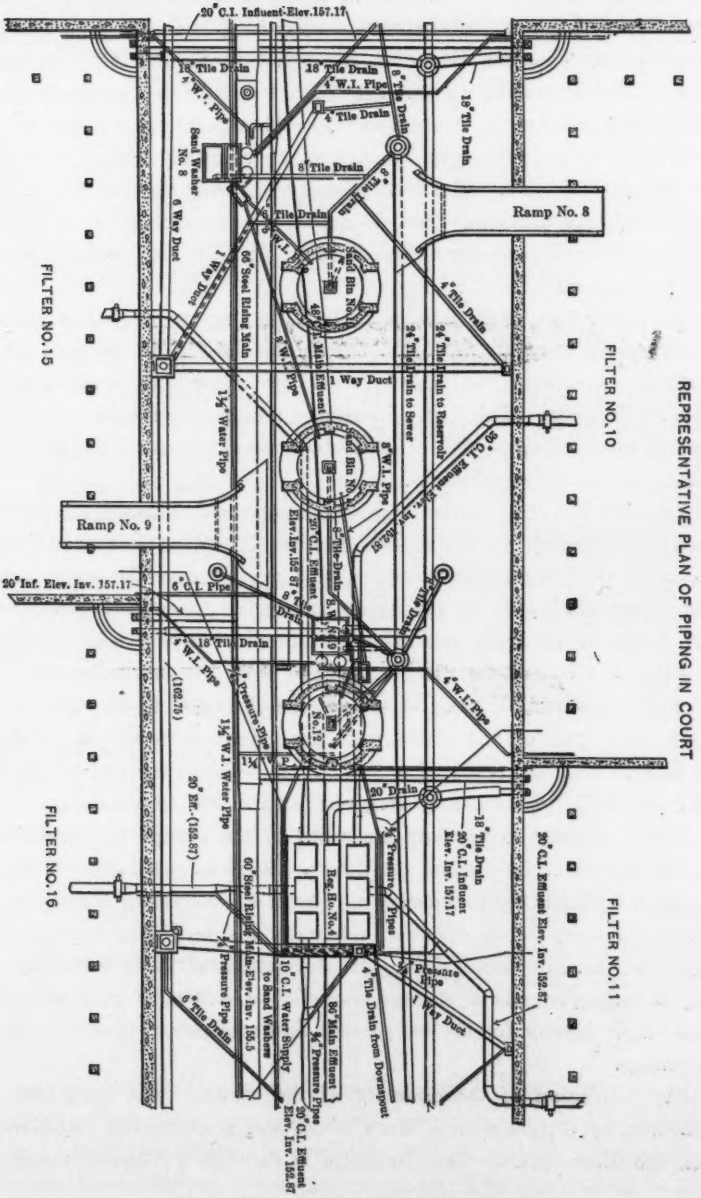

REPRESENTATIVE PLAN OF PIPING IN COURT
FILTER NO. 15
FILTER NO. 10
FILTER NO. 11
FILTER NO. 16
Ramp No. 8
Ramp No. 9
20" C.I. Influent-Elev. 157.17
20" Inf. Elev. Inv. 157.17
18" Tile Drain
4" W.I. Pipe
6" Tile Drain
4" Tile Drain
8" Tile Drain
Sand Washer No. 8
6 Way Duct
1 Way Duct
60" Steel Riding Main
48" C.I. Main Effluent
24" Tile Drain to Reservoir
8" W.I. Pipe
1½" Water Pipe
30" C.I. Effluent
6" C.I. Pipe
Pressure Pipe
1¼" W.I. Water Pipe
20" Eff.-(152.67)
20" Drain
Reg. Bo. No. 4
Pressure Rise
10" C.I. Water Supply
to Sand Washers
20" C.I. Effluent Elev. Inv. 152.67
30" C.I. Effluent Elev. Inv. 152.67
20" C.I. Influent Elev. Inv. 157.17
60" Main Effluent
4" Pressure Pipes
4" Tile Drain from Downspout
Elev. Inv. 156.5
(152.75)

Fig. 8.

*Venturi Meters.*—In each of these lines is built a reinforced concrete Venturi meter. These meters were built with the proportions described by Clemens Herschel, M. Am. Soc. C. E.* One casting was set for the throat of each meter, and another for the entrance. These castings had the usual openings and annular spaces, and were connected with small pipes leading to the registering apparatus in the pumping station. The fittings and registering devices were furnished by the Builders Iron Foundry. The reinforced concrete meters were much cheaper than if made of cast iron, and are perfectly satisfactory.

It would have been possible to build the entire raw-water lines of reinforced concrete, had it not been for the fear of unequal settlements, shrinkage and cracks, and the consequent troublesome leakage of water. The water in these lines is under such pressure that it would usually rise a little above the surface of the courts, were there to be such cracks.

*Regulation.*—The water is pumped from the Washington City Reservoir directly to the filters, and there are no sedimentation basins at the filters. They are unnecessary because the water has been most thoroughly settled before it reaches the plant; and further, there is no space available for them on the site selected, all of which is required for the filters. The piping from the pumps to the filters is so ample that, at the rate of filtration to be used, the water level upon all the filters, with the gates wide open, is nearly the same. The difference of a few inches between the nearest and most remote filters is nearly constant, and is not troublesome.

It is necessary to regulate the speed of the pumps to maintain the desired water level upon the filters. As close regulation of the pumps is difficult, the regulating apparatus of the filters is made so that fluctuations in the levels of the water on the filters through a range of 6 in. are permissible. On an average of 25 filters in service, 6 in. represents a storage capacity of 4 000 000 gal., which gives ample leeway for the convenient and economical operation of the pumps.

The regulation of the quantity of the effluent from each filter is secured by a gate with a large wheel and a graduated standard upon the filter outlet. The discharge is through a Venturi meter,

* *Transactions*, Am. Soc. C. E., Vol. XVII, p. 228.

with suitable apparatus placed directly behind the controlling gate to show the rate of filtration and loss of head. Watchmen observe and record these data at stated intervals, and change the outlet gate when necessary in order to maintain the desired conditions.

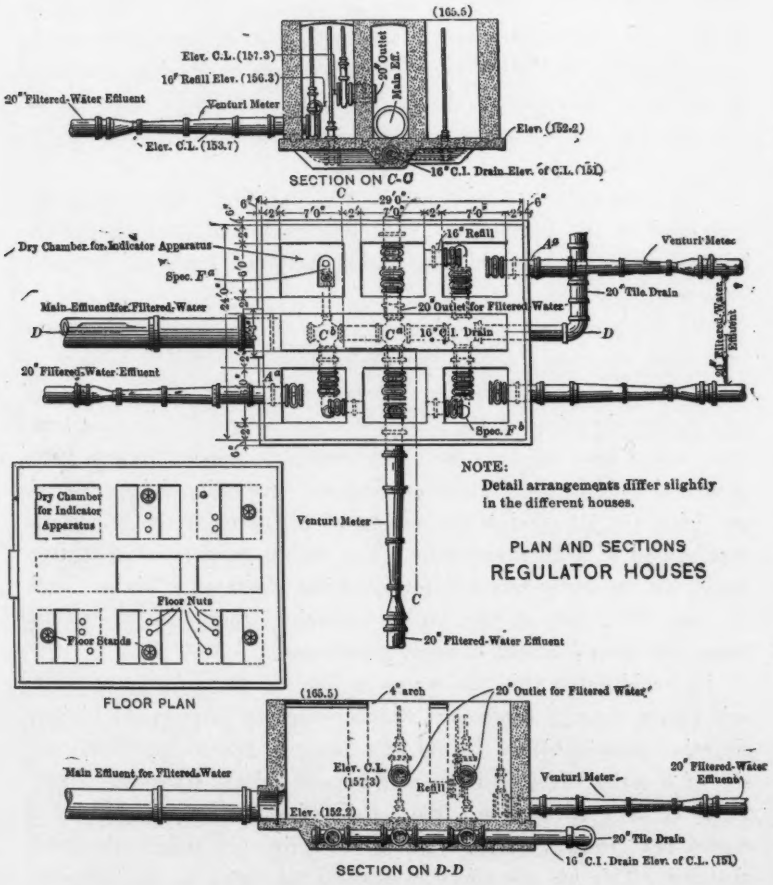



FIG. 9.

This system of regulation was selected in preference to an entirely automatic system, as the required apparatus is much simpler, and no additional labor is involved. This is because watchmen must make the rounds of the filters in any event to see that all is going

well, and it is never necessary to change the adjustments oftener than such rounds would be made.

The pure-water reservoir is arranged so that when it becomes full it will back up water against the filters and reduce the rate of filtration automatically, but the outlets from the filters to the pure-water reservoir are placed at such an elevation that a considerable drop in the pure-water reservoir does not put a corresponding suction or pull upon the filters, but, instead, the loss of head is limited to about 4 ft. Any fall in the water in the pure-water reservoir below the level corresponding to this loss of head has no effect upon the rate of filtration.

The pure-water reservoir has its flow line 18 ft. above the nominal level in the Washington City Reservoir, and 12 ft. above the highest elevation for which provision has been made in the gate-houses of that reservoir.

As the pressure obtained by gravity in the lower part of the city from the works before the filters were built was not large, it would have been desirable to increase it by taking advantage of the higher elevation of the pure-water reservoir. To do this, however, would have required the entire reconstruction of the two gate-houses already in use. These gate-houses were quite elaborate, with provision for all possible by-passing of all parts of the work, and represented a large investment. The designs were such that they could not be easily adapted for handling water at a higher level. To use the water at the higher elevation, therefore, practically meant the abandonment of these gate-houses.

To avoid doing this, the water on leaving the pure-water reservoir passes through controllers which reduce its level to the highest elevation permissible in the old gate-houses. These controllers consist of a series of eight pairs of balanced valves, arranged in batteries of four pairs each. Each pair of valves is operated by a copper float resting on the water in a stilling-box in the discharge chamber. This has the effect of holding the water in this chamber at the desired level.

The balanced valves do not close tightly, but have annular spaces, so that a considerable quantity of water passes them in any event. These spaces were made to pass less water than the assumed minimum rate of consumption, so that the valves are capable of con-

Fig. 10.

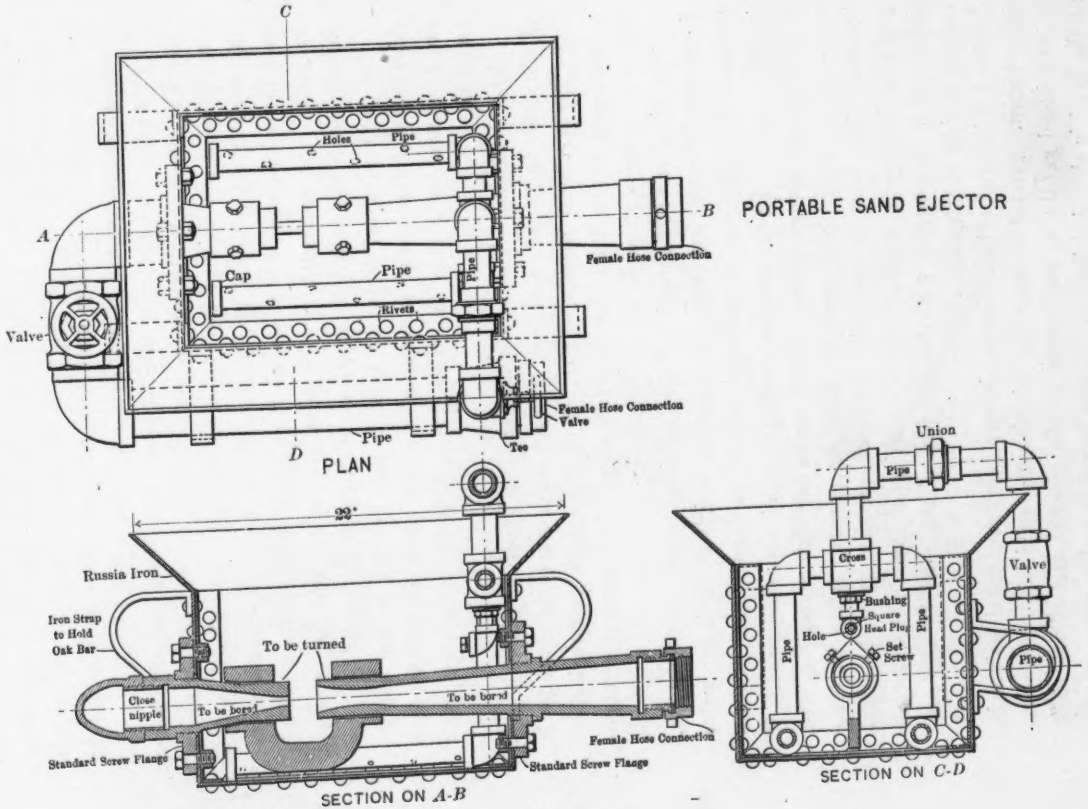

PORTABLE SAND EJECTOR
C
A
B
D
Holes
Pipe
Cap
Pipe
Rivets
Valve
Female Hose Connection
Female Hose Connection Valve
Pipe
Tee
PLAN
22"
Russia Iron
Iron Strap to Hold Oak Bar
To be turned
Close nipple
To be bored
To be bored
Female Hose Connection
Standard Screw Flange
Standard Screw Flange
SECTION ON A-B
Union
Pipe
Cross
Valve
Bushing
Square Head Plug
Hole
Set Screw
Pipe
Pipe
Pipe
SECTION ON C-D

FIG. 10.

trolling through the entire assumed range in consumption. Both the pure-water reservoir and the discharge chamber are provided with overflows back to the Washington City Reservoir, to prevent the water levels from going above the desired heights. A by-pass which can be operated by hand will maintain the supply when the balanced valves are out of service for any reason.

Provision was made to take a large pipe from the pure-water reservoir directly to the city at some time in the future. An opening through the wall of the reservoir was built and closed with a thin wall easily removed, so that this connection can be made whenever the advantage of the increased head becomes important enough to justify the construction of a pipe line connecting the reservoir directly with the distribution system in the city.

In the meantime, the extra head is lost, but the system has the advantage of furnishing an unusually steady pressure, for the pipes are protected from even the fluctuations in level in the pure-water reservoir.

*Sand Washing.*—The sand-washing and handling plant is one of the most important features, because the work to be done by it is by far the most expensive part of the operation, and makes up a large part of the total cost of purification. The general arrangements of these appliances are as follows:

The dirty sand is scraped off and piled up by men with shovels. It is then thrown into movable ejectors, which force it by water pressure through lines of hose and pipe to stationary sand washers in the courts. These washers clean the sand and also elevate it to cylindrical storage tanks. These tanks are high enough so that carts drive under them and are filled by opening gates in their bottoms. The carts in turn take the sand over the top of the filters and drop it through manholes upon revolving chutes, in the manner described in connection with the placing of the sand by the contractor during construction.

*Sand Ejectors.*—The movable ejectors have two novel points in their design. First, the water for bringing the sand into suspension is introduced gently at the bottom of the ejectors and slowly rises as the sand is shoveled into it. It was found by experiments, made under the authority of Colonel Miller, that sand could be more effectively loosened and suspended in this way than by playing water

Fig. 11.

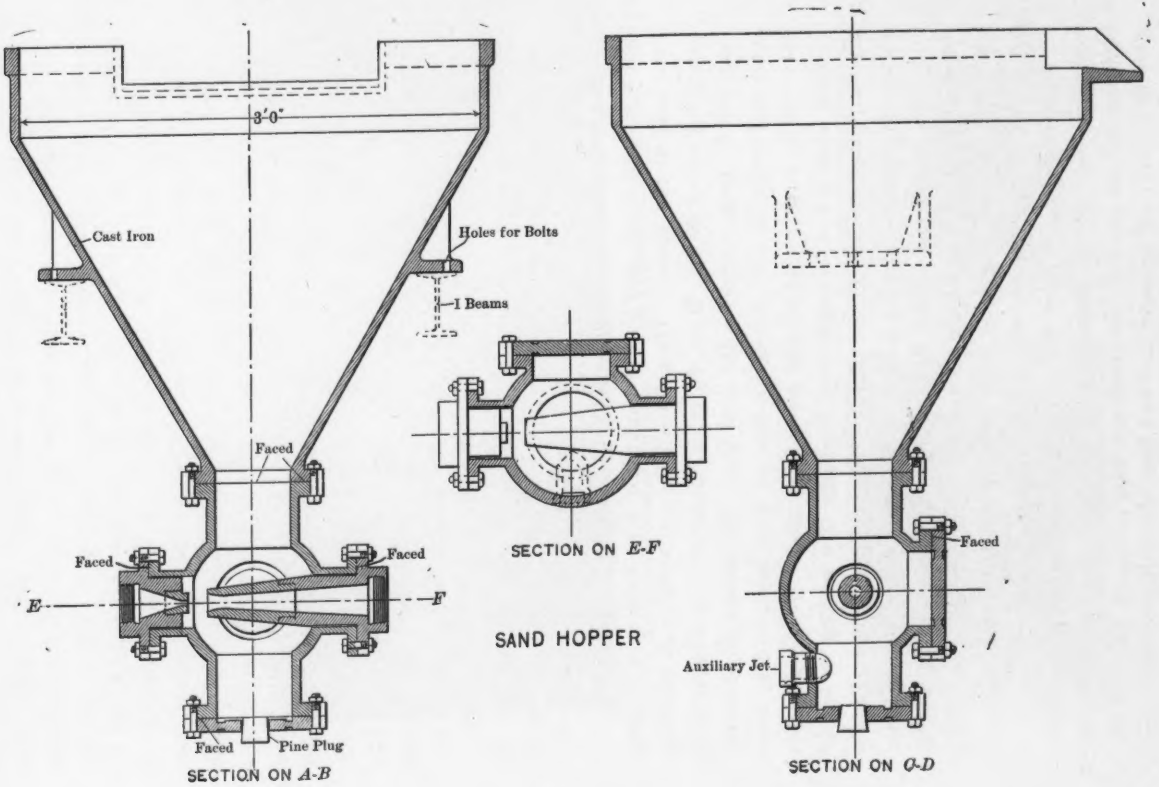

3'-0"
Cast Iron
Holes for Bolts
I Beams
Faced
Faced
Faced
E
F
Faced
Pine Plug
SECTION ON A-B
SECTION ON E-F
SAND HOPPER
Faced
Auxiliary Jet
SECTION ON C-D

FIG. 11.

upon it from above at considerable velocity. The mixture thus produced contains more sand in proportion to the water, and the ejectors therefore throw more sand and less water. Second, the discharge ends of the ejectors beyond the throats are made with a very flat batter, like the discharge end of a Venturi meter. The batters for the discharge are 1 to 22, in place of 1 in 6, used at Lawrence, Albany, Philadelphia and in other earlier designs. A series of tests showed that with this modification, and with fixed water and sand quantities, twice as much pressure at the discharge could be obtained as with the usual batter on the discharge. In other words, with given quantities of sand and water, it is possible to force the sand through twice as long a line of discharge piping, by the use of the flatter batter in the discharge pipe beyond the throat of the ejector. The saving clearly comes from the utilization of the velocity head in the throat, which was largely lost with the greater batter on the discharge.

Water to operate the movable ejectors and all other parts of the sand-washing and handling system is provided under from 80 to 100 lb. pressure by pumps and pipes installed for that purpose. Unfiltered water from the main pump-well is used. The pipes take the water to each court, and 5-in. wrought-iron pipe lines take it down each side of the filters. These have hose connections at intervals averaging about 60 ft. Hose, 2½ in. in diameter, and seldom more than 100 ft. long, completes the feed line. The discharge of mixed sand and water is first through a line of 3-in. hose, seldom more than 100 ft. long, to the nearest side of the filter. Here connection is made with a 4-in. wrought-iron discharge line leading to one of the stationary washers in the courts. The feed and discharge pipes always go together, making a pair, with corresponding connections, and with connections under the vaulting but above the top of the filter walls, so that each pair is capable of serving two filters. The pipes are also laid to grades, with blow-offs, so that when they are not in use they can be entirely drained to prevent freezing.

The design of the pipes for carrying the mixed sand and water was given considerable attention. If they were too small, the capacity would be limited; the workmen would have to wait for the ejectors to carry off the sand that had been shoveled into them; and the apparatus would not prove economical. On the other hand, if the

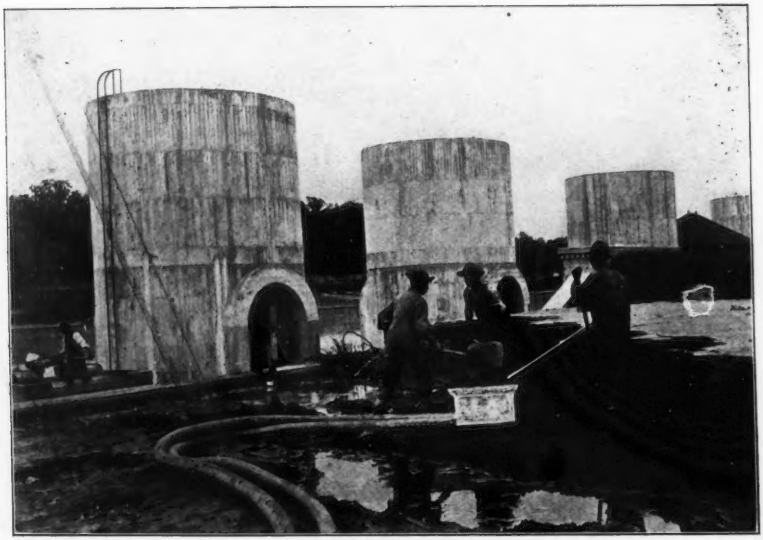


FIG. 1.—MOVABLE EJECTOR AT WORK MOVING SAND TEMPORARILY STORED ON TOP OF A FILTER.

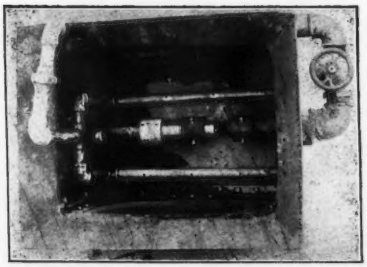


FIG. 2.—MOVABLE SAND WASHER.

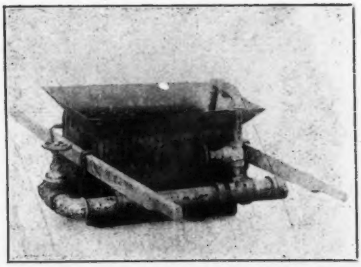


FIG. 3.—MOVABLE SAND WASHER.

pipes were too large for the minimum use, the sand would settle out of the water, form a deposit in the pipes, and stop the operation.

By authority of Colonel Miller, tests were made to determine the power and capacity of ejectors of different sizes and types, the frictional resistances of mixtures of sand and water in pipes, and the minimum velocities at which such pipes could be regularly operated without stoppage by separated sand.

In making these tests an ejector was connected by hose to a length of wrought-iron pipe, which finally discharged into a tank on a wooden trestle. The outlet from this tank was through a circular hole in a disc of sheet-iron upon the bottom, which acted as a standard orifice. Pressure gauges connected with the pipe at intervals gave better results as to loss of head than could be secured by differential gauges of glass tubes. There is a throbbing in pressure, particularly at moderately low velocities, perhaps due to a partial deposition and subsequent picking up of sand particles, and to separations into more and less dense mixtures, which made it difficult to get satisfactory readings in the glass tubes. The pressure gauges were less sensitive and therefore much more easily read, and, on the whole, sufficiently accurate.

The time required to throw a measured volume of sand was observed by one man, while others read the gauges on the discharge pipe at 10-sec. intervals. At the same time the head over the standard orifices was noted, and from this the total volume of flow was computed.

Occasionally, the discharge from the orifice was taken by a spout to a tank for a determined interval. The results thus secured were used to compute the coefficient of discharge of the orifice (which was 0.63 for sand mixtures, in place of 0.60 for water, probably because the sand formed a flat cone about the orifice). The sand contained in this water was also often separated and measured, as a check on the rate at which it was passing.

Such experiments were made with 3-in. and 4-in. pipe, from which diagrams of friction were prepared for use in designing the piping for the filters. They are not as accurate as could be wished, and further data of this kind are to be desired.

With an average velocity as low as 2 ft. per sec., a pipe would promptly fill up with sand and shut itself off. This was true, what-

ever proportion of sand was present in the water. At 2½ ft. per sec. flows of sand and water were sometimes maintained, but always with great fluctuations in friction, which, the writers think, indicates a partial deposition of coarse particles and an occasional picking up and carrying forward of an accumulation. Occasionally, at this velocity, the pipe would fill so as to shut off the flow.

At velocities of 3 ft. per sec. the flow was much steadier, and stoppages almost ceased. At 4 ft. per sec. and upward, mixtures of sand and water acted quite as a fluid, and the flow was almost as steady and regular as that of so much water, although the frictional resistance was much greater.

As a result of these studies, and calculations based upon them, it was concluded that:

A short length of 3-in. hose or pipe would not throttle an ejector too closely, but a line of such pipe long enough to serve the most distant positions of the movable ejectors would cut down the rate of discharge to such an extent that the men would have to do too much waiting for the ejectors.

It would never be possible to discharge two ejectors through the same 3-in. pipe.

Adequate carrying capacity is furnished by 4-in. pipe, and one such pipe will usually be capable of taking the discharge from two ejectors, if occasion demands.

To prevent obstruction in 4-in. pipe, the jet of the ejector should be of such size as to throw water enough to produce a velocity of 3 ft. per sec. in 4-in. pipe. In practical operation the sand taken up and the water introduced through the irrigator will increase the volume by one-third, and will produce a velocity of 4 ft. per sec. in the 4-in. discharge, and this is desirable.

With two ejectors discharging through one 4-in. pipe, the velocity in it will be about 8 ft. per sec., which is permissible.

The most advantageous ratio of diameter of jet to throat in ejectors was studied at some length, and sufficient information secured to select a throat diameter of approximately the most advantageous size. A diagram of some of these results was made, which shows the results clearly.

A large throat will throw more sand, but the pressure that can

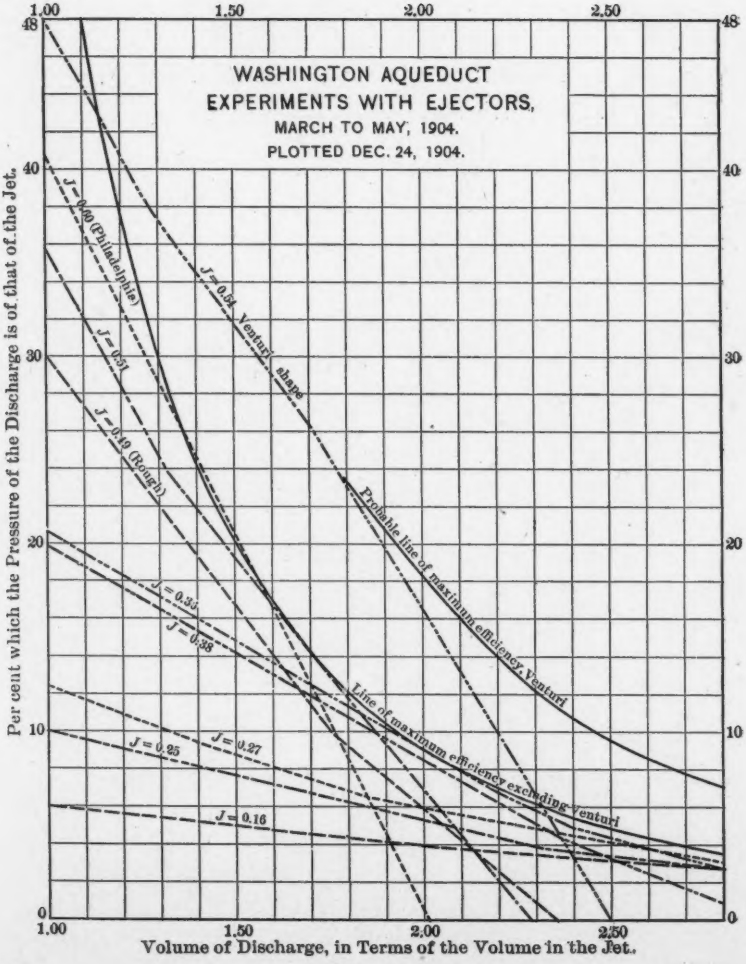

WASHINGTON AQUEDUCT
EXPERIMENTS WITH EJECTORS,
MARCH TO MAY, 1904.
PLOTTED DEC. 24, 1904.
J = 0.49 (Philadelphia)
J = 0.51
J = 0.49 (Rough)
J = 0.54 Venturi shape
Probable line of maximum efficiency Venturi
J = 0.35
J = 0.38
Line of maximum efficiency exceeding Venturi
J = 0.25
J = 0.27
J = 0.16
Per cent which the Pressure of the Discharge is of that of the Jet.
Volume of Discharge, in Terms of the Volume in the Jet.
1.00
1.50
2.00
2.50
0
10
20
30
40
48

FIG. 12.

be produced to overcome friction in the piping decreases almost as the square of the throat diameter. The ratio of jet to throat, as computed for the different ejectors, based on the data of the experiments, varied greatly. For instance, in the movable ejector,

FLOW OF SAND AND WATER IN THREE-INCH PIPE.
FROM EXPERIMENTS MADE FOR WASHINGTON AQUEDUCT
MARCH AND MAY, 1904
PLOTTED, MAY 13, 1904

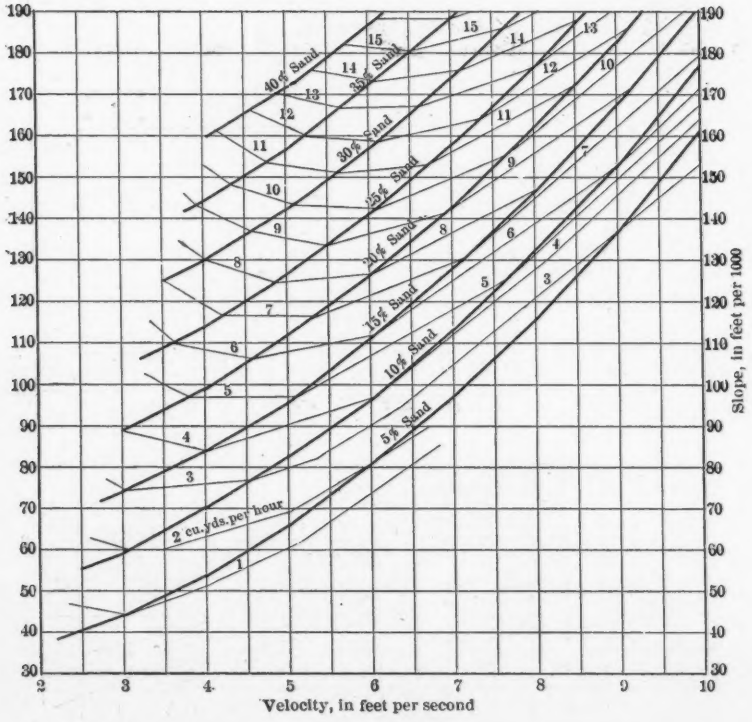



FIG. 13.

the jet is 0.59 of the throat. In the first ejector in the stationary washers, which only throws the sand from one hopper to the next, the ratio is 0.34, and in the second one, which lifts the sand to the sand-bin, the computed economical ratio is 0.48. In all cases the

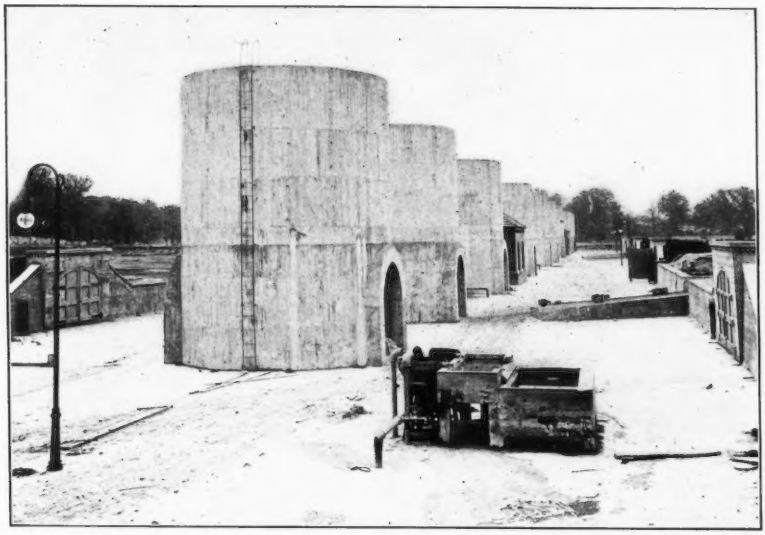


FIG. 1.—GENERAL VIEW OF COURT, SHOWING SAND WASHER, SAND STORAGE BINS, ETC

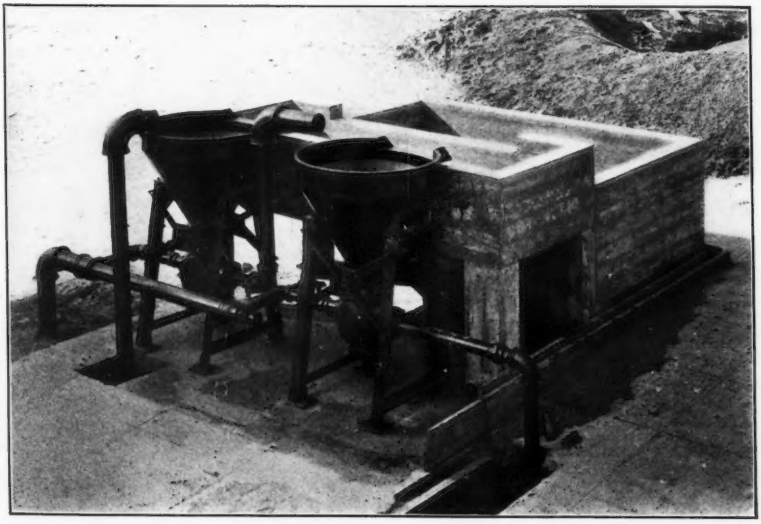


FIG. 2.—STATIONARY WASHERS.

ratios are changed by wear, and the throats will need to be replaced frequently.

*Sand Washers.*—The stationary washers in the courts are somewhat like the washers at Albany, but differ in one important particular. The mixed sand and water falls into a hopper, but below this is a chamber formed by a globe casting. There is a free opening from the hopper to this chamber. A secondary jet of water (called an "irrigator") enters this casting near the bottom, and supplies just about the quantity of water which is carried into the throat of the ejector with the sand as it leaves the hopper. By this arrangement there is no downward flow of water from the hopper to the chamber below. The sand settles through the water into the chamber, and is separated from practically all the dirty water which came with it. This overflows from the top of the hopper and is wasted.

In the Albany washers, each hopper serves to dilute the dirty water in the sand which reaches it. In a general way, each hopper serves to reduce the foreign matter by one-half. In the new type there is practically a complete separation, and theoretically a single hopper should serve to wash the stand adequately. As an added safeguard, a second hopper is provided, however, which may or may not be used, as desired.

This type of sand washer was designed by one of the writers for another service,* and has since been used in smaller plants.

The waste water from the hoppers goes through a pair of concrete boxes, to stop such particles of sand as may be carried out of the hoppers, and this sand is shoveled back to the washers from time to time.

The stationary washers and their appurtenances are erected on blocks of reinforced concrete, strong enough so that any movement, either from settlement or frost, will move the block and the apparatus as a whole, and will not move the different parts of it in relation to each other.

The available space in the stationary washers did not permit the use of a batter of 1 in 22 on the ejectors, but a batter of 1 in 14 was obtained. This produces an ejector powerful enough to lift the sand about 26 ft., to the top of the storage bins.

* Described in *The Engineering Record*, January 25th, 1902, and in *Engineering News*, February 13th, 1902.

*Sand Bins.*—The storage bins are of reinforced concrete, cylindrical in form, with conical bottoms. They are supported on circular concrete foundations, carried well below the frost line, and also below the pipes in the courts. The weight of the bins is carried partly upon an outside wall and partly upon three circular arches which intersect in the center of the structure, leaving a space underneath large enough for a two-horse cart to drive through to be filled with sand from the gate.

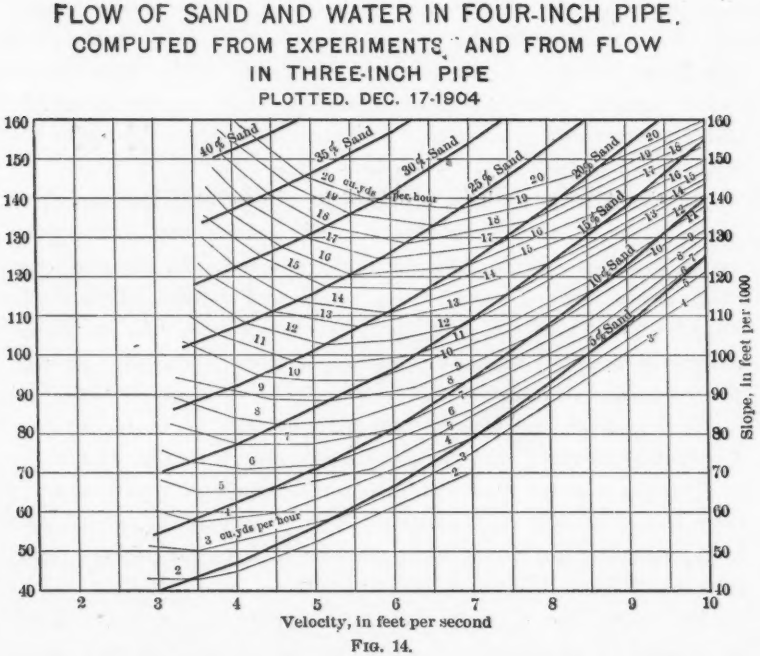



FIG. 14.

Each bin holds 250 cu. yd. as it can ordinarily be filled, which is not quite to the top. The material thrown to these storage bins consists of 1 part of sand and 3 or 4 parts of water. The sand settles to the bottom, and the water accumulates in the bin until the latter is half full. It then overflows through a pipe at this level, and this continues until the sand nearly reaches the outlet. The gate on the first outlet is then closed, and the process is repeated by the use of a second outlet almost at the top of the bin.

Twenty-nine bins are provided, one for each filter, but the connections are such that each filter is tributary to a number of bins. The filters and bins are arranged in three groups. The bins in each group will contain sand equivalent to 19 in. on one filter, or somewhat more than the quantity to be replaced at one refilling of a filter. The plan is to refill a filter as often as the bins are full, and to use all the accumulated sand in one group in doing it. This will be every two or three months.

There may be seasons of the year when it will not be wise to replace the sand in the filters. Experience at Albany indicates that, after replacing sand, the quality of the effluent temporarily falls off somewhat. In summer the change is slight and unim-

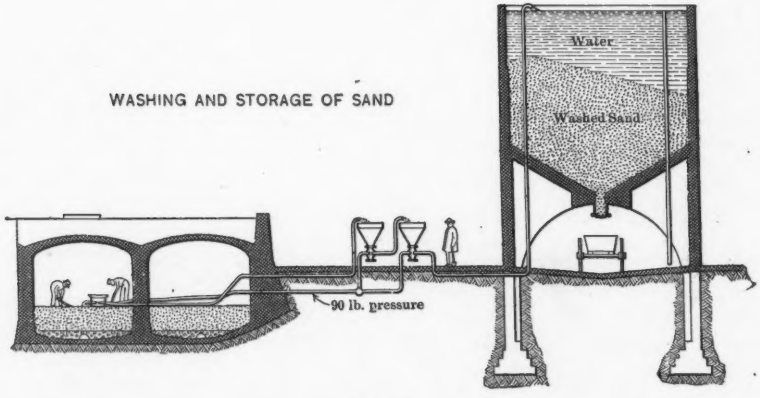



FIG. 15.

portant. In colder weather it is much greater. If this proves to be the case at Washington, refilling will not be advisable in winter; and after the bins are once filled with sand in cold weather, the remainder of the sand removed from the filters will be piled up in the courts until spring. Computation showed that the saving in labor and handling sand would make it pay to build bins where they could be used several times a year, but that it would not pay to build them when they could be used only once a year. No bins are provided, therefore, for this exceptional winter condition, and, as far as it occurs, the sand in excess of the capacity of the bins will be handled by the older methods.

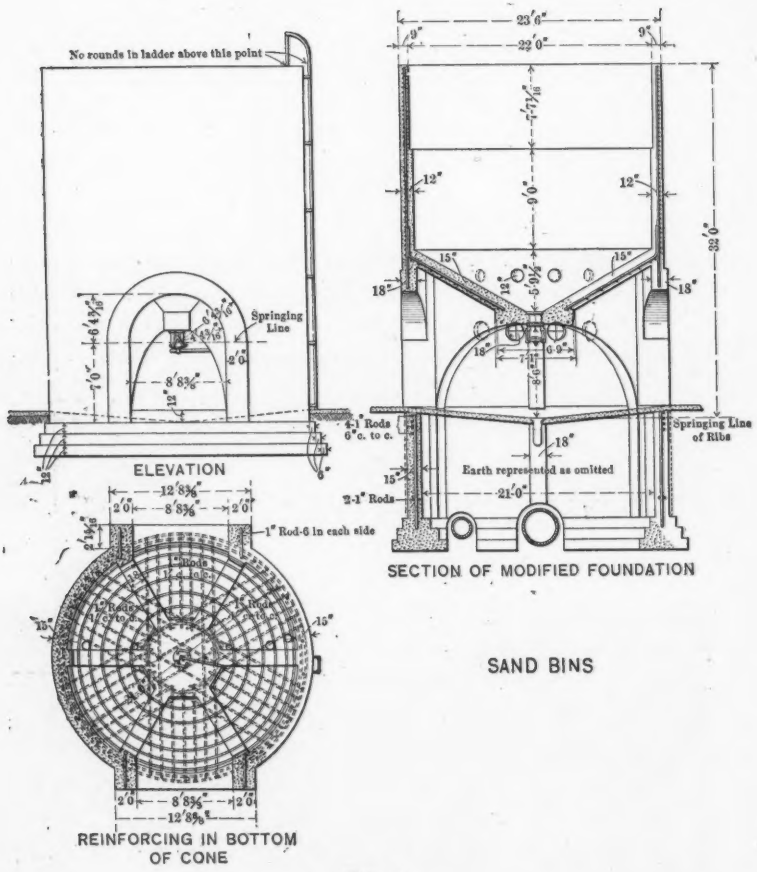



FIG. 16.

The sand handling machinery was completed so that it was in use for the greater part of the work from the last of April, 1906. The figures thus far obtained indicate average costs for labor as follows:

| | | |
|---|---|---|
| Scraping ..... | 5 | cents per cu. yd. |
| Ejecting ..... | 16 | " |
| Washing ..... | 5 | " |
| Storing and replacing | 13 | " |
| Total cost ..... | 39 | cents per cu. yd. |

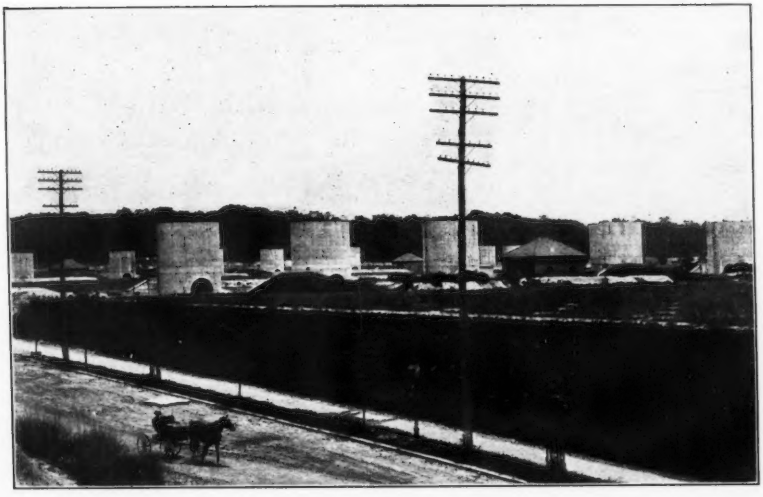


FIG. 1.—GENERAL VIEW OF A PART OF THE WASHINGTON FILTRATION PLANT.

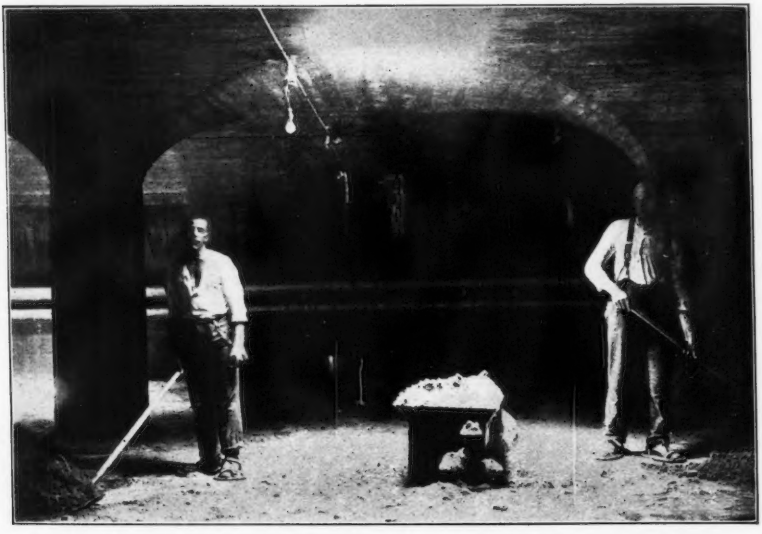


FIG. 2.—MOVABLE EJECTOR AT WORK MOVING SAND FROM FILTER.

These figures may be revised, with more extended experience, but the present indication is that the entire cost of sand handling will not exceed 40 cents per cu. yd. The apparatus has fully justified the additional investment, for the cost is far lower than has been yet reached elsewhere.

For comparison, the average costs of sand handling, as computed by George W. Fuller, M. Am. Soc. C. E.,* for some of the older filters, are as follows:

| | | |
|---|---|---|
| Lawrence, in service, 1893..... | $1.70 | per cu. yd. |
| Mount Vernon, in service, 1894.. | 1.51 | " |
| Albany, in service, 1899..... | 1.38 | " |

From data in published reports it appears that the cost at Philadelphia, with hydraulic ejecting, is about $1.20 per cu. yd.

It should be stated that the average depth of sand removed at Washington is greater than at the other places, but that the scrapings are less frequent; so that the quantity of sand handled per million gallons is about an average figure.

*Pumping Station.*—The pumping station serves to lift the water from the Washington City Reservoir to the filters. In the same building are located, also, the pumps which supply raw water under high pressure for washing and transporting the sand; an electric light plant; boilers and other auxiliary machinery. When the Washington City Reservoir is at its normal high-water mark, it is 20 ft. below the level of the water on the filters. To this must be added about 1 ft. for frictional loss in the piping, including the head loss in the Venturi meters. This makes the normal minimum pumping lift 21 ft. The Washington City Reservoir will not always be entirely full, however. When it is drawn down the pumping lift will be increased. It is possible to draw it approximately 14 ft., in which case the pumping lift will be increased to 35 ft. The capacity of the reservoir between these levels is 180 000 000 gal.

The main pumping is done by three centrifugal pumps, directly connected to Harrisburg engines, all furnished by the Henry R. Worthington Company. These pumps at the minimum lift are guaranteed to deliver 40 000 000 gal. per 24 hr. They have ac-

*Transactions*, Am. Soc. C. E., Vol. XLVI. p. 386.

tually delivered nearly 25% more than the guaranty. At greater lifts the guaranteed capacity decreases, so that the product of the capacity and lift is always 840 000 000. The guaranteed duty was 100 000 000 ft-lb. per 1 000 lb. of dry steam. On test the duty developed was 97 500 000 ft-lb.

It was found that there was considerable loss of head in the surface condensers on the discharge, and the contractors are now changing these condensers. The saving made in this way will represent more than the deficiency in the duty, so that the pumps will fully comply with the guaranty.

There are two pumps for the sand wash-water, each with a capacity of 2 500 000 gal. per 24 hr., with 100 lb. pressure. It is expected that one pump operated through one 8-hr. shift per day will generally maintain this service. Occasionally, it may be necessary to operate two pumps, or to extend the period of work beyond 8 hr. per day. The pumps are compound, designed to stand rapid fluctuations in rate and pressure, and are not designed to give the greatest economy. The duty shown on test was about 65 000 000 ft-lb. per 1 000 lb. of steam, thus exceeding the guaranteed duty of 60 000 000 ft-lb.

The electric-light equipment consists of one 50- and one 25-kw. generator, directly connected to compound steam engines. This serves to light the pumping station, the office and laboratory, and the courts, and furnish current for other incidental purposes. The filters are also wired and provided with electric light throughout. There is one 16-c.p. light for each 14-sq. ft. section. Generally, to clean the filters, the manhole covers will be removed, admitting daylight. The daylight secured in this way is more satisfactory and cheaper than the electric light, but experience in other places has shown that there are dark days, or times when snow and ice are upon the roof, and when it is a great convenience to be able to clean without removing the covers. The electric lights in the filters, therefore, are regarded as for occasional and auxiliary use, and not for regular service.

Steam is furnished by four 200-h.p. Babcock and Wilcox boilers, with Roney automatic stokers and Green economizers. A Custodis stack, 150 ft. high and 5½ ft. in diameter, serves the boilers.

A coal pocket adjoining the boiler-room is of concrete, and of

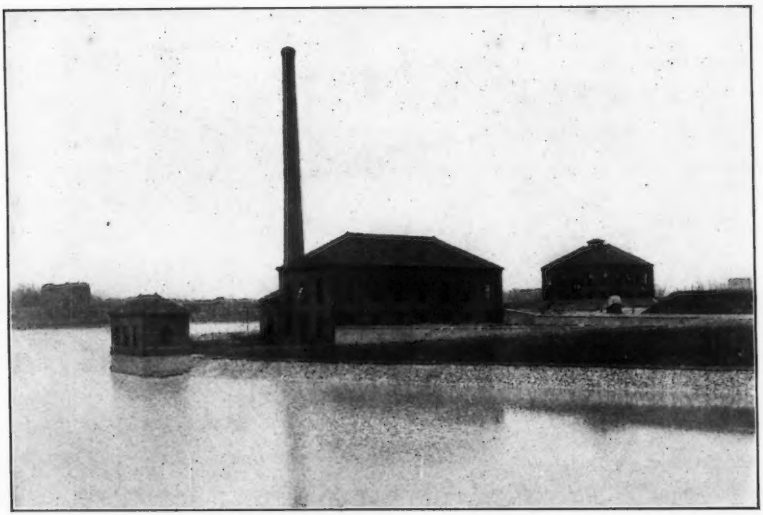


FIG. 1.—PUMPING STATION, OFFICE AND LABORATORY BUILDING, AND INTAKE GATE-HOUSE, AT WASHINGTON CITY RESERVOIR.

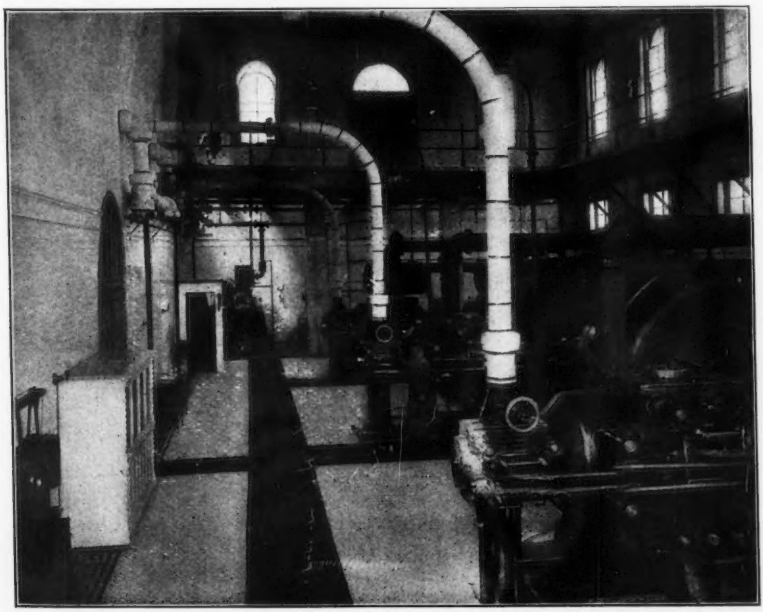


FIG. 2.—INTERIOR OF PUMPING STATION.

practically the same construction as the filters. It is 68 ft. square, with an inside height of 15 ft., and will hold 1 700 tons of coal, or four months' supply.

It is not possible to get a track from any railroad to the plant. Coal, therefore, must be brought in carts; and manholes are provided through which the coal is dumped from the driveway into the pocket.

*Laboratory.*—The laboratory and office building is 36 by 56 ft., with a high, light basement. It is placed near the pumping station, and high enough so that a good general view of the plant is obtained from its windows. The design follows in a general way that of the original laboratory of the Lawrence Experiment Station of the Massachusetts State Board of Health, having a general laboratory with a roof ventilator in the middle, with special laboratories for chemical and biological work on either side. The superintendent's office immediately adjoins, while the filter foremen and gate tenders have an office across the hall, in which many of the routine records are kept. The basement furnishes storage for supplies, and room for experiments on a considerable scale.

The laboratory department has charge of the routine operation of the filters, and is responsible for the results obtained. It must also keep track, and investigate the condition, of the water from Great Falls to the plant, and note the changes that take place in the aqueducts and reservoirs. It is intended, further, to make experiments upon methods of treating the water with reference to improving the processes and the suggested methods of preliminary treatment.

*Cost of Work.*—The total sum appropriated for the construction of the filters was $3 468 405. Nearly all the work is finished and paid for, although a little finishing up remains to be done.

Taking the payments, as far as made, and estimating the cost of the parts yet to be completed, a statement of the approximate cost of the work has been prepared (Table 2), and this will not differ greatly from the final figures.

TABLE 2.—APPROXIMATE COST OF WASHINGTON FILTRATION PLANT.

| | |
|---|---|
| *Pumping Station:* | |
| Intake, with gates and building | $11 500 |
| Venturi meters, 72-in. and 54-in. (reinforced concrete) | 5 000 |
| Electric lighting, engines, etc. | 7 000 |
| Four 200-h.p. boilers, in place | 14 800 |
| Four Roney stokers | 4 100 |
| Two Green economizers, in place | 5 100 |
| Three 36-in. centrifugal pumps, with engines | 42 000 |
| Two sand-washer pumps | 8 100 |
| Piping, valves, etc. | 13 100 |
| Coal, oil, and running tests | 3 500 |
| Traveling crane | 1 600 |
| Chimney, with foundation | 5 800 |
| Coal vault | 11 000 |
| Building, with foundation and suction well | 51 000 |
| Total cost of pumping station | $183 600 |
| *Twenty-nine Filters:* | |
| Excavating, 862 700 cu. yd., at 30 cents | $258 800 |
| Filling, 299 500 cu. yd., at 30 cents | 89 900 |
| Sodding slopes, and seeding | 7 300 |
| Roads and drains outside of filters | 16 200 |
| Concrete tunnel under First Street | 3 100 |
| Concrete (including cement). | |
| Floors, 36 563 cu. yd., at $6.75 | 246 800 |
| Walls, 19 038 cu. yd., at 7.35 | 139 900 |
| Piers, 6 964 cu. yd., at 8.25 | 57 500 |
| Vaulting, 34 920 cu. yd., at 8.75 | 305 500 |
| Ramps leading to tops of filters | 6 800 |
| Court paving (including cement) | 43 000 |
| Central underdrains, 7 900 lin. ft., at $1.65 | 13 000 |
| Interior drainage system, 29 filters, at $500 | 14 500 |
| Drainage of roofs, 29 filters, at $266 | 7 700 |
| Materials placed in masonry, 29 filters, at $200 | 5 800 |

| | |
|---|---|
| Doors and beams at entrances | $3 700 |
| Filter sand, 157 725 cu. yd., at $2.65 | 418 000 |
| Filter gravel, 36 500 cu. yd., at $2.75 | 100 400 |
| Cast-iron piping and special castings | 117 000 |
| Steel rising main, including concrete backing | 76 800 |
| Pressure-pipe system | 2 600 |
| Sand-washer pipe system, complete | 24 000 |
| Sand-washing apparatus, 19 washers, 8 ejectors, and hose connections, complete | 4 800 |
| Elevated sand bins, 29, capacity 250 cu. yd. each | 60 800 |
| Exterior drainage system | 25 300 |
| Venturi meters and indicating apparatus | 11 400 |
| Sluice gates and gate-valves | 19 900 |
| Regulator-houses, including substructures | 27 300 |
| Office and laboratory, with equipment | 19 700 |
| Shelter-house for workmen | 4 800 |
| Water and gas lines to buildings | 11 200 |
| Electric lighting, courts and filters | 41 900 |
| Cleaning up and miscellaneous | 11 600 |
| Total cost of 29 filters | $2 197 000 |

*Filtered-Water Reservoir:*

| | |
|---|---|
| Excavation, 83 500 cu. yd., at 30 cents | $25 100 |
| Filling, 18 000 cu. yd., at 30 cents | 5 400 |
| Concrete (including cement), 15 290 cu. yd. (average) $7.60 | 116 000 |
| Gate-houses for filtered-water reservoir (superstructure) | 3 500 |
| Total, filtered-water reservoir | $150 000 |

*Lower Gate-house:*

| | |
|---|---|
| Pipe lines to lower gate-house | $6 000 |
| Lower gate-house | 18 300 |
| Total | $24 300 |

| | |
|---|---|
| *Land* | $619 900 |
| *Clerical and Engineering Work:* | |
| General plans | $36 000 |
| Surveying | 32 000 |
| Field office force | 21 000 |
| Main office force | 20 000 |
| Inspecting work and testing materials | 67 000 |
| Watchmen | 4 500 |
| Temporary office | 1 000 |
| Total, clerical and engineering | $181 500 |

SUMMARY.

| | |
|---|---|
| Pumping station, including intake, Venturi meters, electric light generating apparatus, concrete, and stack, complete | $183 600 |
| Twenty-nine filters, with excavation, grading, concrete work, piping, regulator-houses, shelter-house, laboratory and office, electric light wiring, sand-washing apparatus, sand bins, etc., complete | 2 197 000 |
| Filtered-water reservoir, including excavation, concrete work, gate-house, regulating apparatus, etc., complete | 150 000 |
| Lower gate-house and pipe line | 24 300 |
| Land | 619 900 |
| Engineering and clerical work | 181 500 |
| Total cost of work | $3 356 300 |
| Total amount appropriated | $3 468 400 |
| Balance available for operation and contingencies | 112 100 |
| Total cost for construction, excluding land | $2 736 400 |
| Percentage for engineering and supervision | 6.65 |

*Cost of building per square foot* (outside dimensions of brickwork):

| | |
|---|---|
| Pumping station | $6.70 |
| Regulator-houses (including substructure) | 6.63 |
| Shelter-house | 3.24 |
| Intake (including substructure) | 21.30 |
| Lower gate-house (including substructure) | 14.95 |
| Gate-house (filtered-water reservoir) | 3.10 |
| Office and laboratory | 6.45 |

Cost per acre for constructing 29 filters:

$2 197 000 ÷ 29 = ..... $75 700

Cost per million gallons capacity of filtered-water reservoir:

$150 000 ÷ 14.2 = ..... 10 600

## Comparison of Costs of Construction at Albany and at Washington.

The Washington filters cost about 65% more, in proportion to their net area, than the Albany filters. Most of this is caused by higher unit prices. Masonry cost 20% more per cu. yd., and on other items there was a general increase of fully 25%, representing the changed business conditions at the two periods of construction. Fully as much more was caused by the supposed difficulty of securing filter sand at Washington, a difficulty which proved to be unfounded.

The costs may be compared as follows:

| | |
|---|---|
| The masonry was lighter at Washington and the sand thinner, representing a reduction in the whole cost of the work of about | 11% |
| The cost of construction was increased because of the irregularity of the site, and the extra earthwork and filling required, increasing the whole cost of the work by about | 16% |
| Electric lights, sand bins and appurtenances, not used at Albany, were added, increasing the whole cost of the work by about | 6% |
| The unit prices were higher (those of filtering materials making one-half of the addition) increasing the whole cost of the work by about | 50% |

The product of these factors,

$$0.89 \times 1.16 \times 1.06 \times 1.50$$

is 1.65, or approximately the relative cost of the Washington work.

*Operation.*—The first filter was put in operation on August 18th, 1905. The effluent from this filter was mixed with the usual supply of unfiltered water in the Washington City Reservoir. One additional filter was started every second day thereafter, until October 5th, when the raw water was cut off and the entire city was supplied with filtered water.

Unfortunately, the laboratory building and apparatus had not been completed at the time the first filter was put into service, but they had reached such a state of completion early in September that samples of the unfiltered and filtered water were plated each day and counts of bacteria made.

Between August 22d and 31st, the turbidity of the water in the reservoir supplying the filters, as determined by the U. S. Geological Survey standard, ranged between 30 and 45 parts per million, and averaged 40. During the first 12 days in September, the turbidity of this water was higher, ranging between 40 and 85, after which it decreased, and was uniformly low until December 8th, when it began to increase again.

The reduction in turbidity of the filtered water was noticeable the very first day after each filter was put into service, and a fair percentage of reduction was invariably shown thereafter.

During October it became necessary to clean some of the filters. On account of the filters having been put into operation before the completion of all their appurtenances, the work of cleaning was considerably greater than would otherwise have been the case. At this time the courts had not been paved, nor had the sand washers and sand-washer pumps been put in condition for use. In consequence, the old method of removing sand in wheel-barrows had to be used, and not only that, but it had to be wheeled on temporary runways to the top of the filters, which added to the expense of scraping, not only for the additional distance and elevation, but for the construction of the runways.

The pumping plant was in the hands of the contractor for a part of the time, and irregularities in service during the tests added to the cost of operation.

Some of the leading data of operation for the first five months are shown in Tables 3, 4, 5 and 6.

## TABLE 3.—Turbidity.

### Averages by Months.

| Month. | Great Falls. | Reservoirs. | | | Filtered water. |
|---|---|---|---|---|---|
| | | Dalecarlia. | Georgetown. | Washington City. | |
| 1905 | | | | | |
| October | 36 | 21 | 18 | 11 | 1 |
| November | 19 | 19 | 14 | 11 | 1 |
| December | 199 | 84 | 74 | 39 | 6 |
| 1906 | | | | | |
| January | 94 | 60 | 60 | 52 | 12 |
| February | 45 | 41 | 29 | 22 | 3 |
| March | 272 | 181 | 56 | 46 | 6 |
| April | 167 | 72 | 58 | 46 | 7 |
| May | 56 | 20 | 16 | 10 | 2 |
| June | 303 | 125 | 94 | 41 | 2 |

This operation was without coagulant, and the turbidity of the effluent clearly shows the need of it.

## TABLE 4.—Bacteria.

### Averages by Months.

| Month. | Reservoirs. | | | Filtered water. |
|---|---|---|---|---|
| | Dalecarlia. | Georgetown. | Washington City. | |
| 1905. | | | | |
| October | ..... | ..... | 198 | 78 |
| November | ..... | ..... | 153 | 27 |
| December | 15 637 | 17 884 | 3 750 | 60 |
| 1906. | | | | |
| January | ..... | 15 719 | 1 520 | 39 |
| February | 4 086 | 1 823 | 562 | 16 |
| March | 1 105 | 883 | 654 | 19 |
| April | 1 658 | 715 | 399 | 22 |
| May | 206 | 94 | 66 | 17 |
| June | 4 628 | 334 | 224 | 17 |

TABLE 5.—PUMPING PLANT.

| | Average number of million gallons pumped to filters. | Average lift, in feet. | Average quantity of sand wash-water pumped 100 lb. pressure. | Pounds of coal burned. | Duty of plant per 100 lb. coal burned. |
|---|---|---|---|---|---|
| 1905. | | | | | |
| October | 67.9 | 23.3 | ..... | 19 382 | 68.9 |
| November | 66.1 | 21.6 | ..... | 17 198 | 69.4 |
| December | 67.2 | 21.5 | ..... | 19 899 | 60.4 |
| 1906. | | | | | |
| January | 65.27 | 21.6 | ..... | 20 659 | 57.2 |
| February | 68.69 | 21.2 | ..... | 20 264 | 61.1 |
| March | 64.28 | 20.1 | ..... | 18 494 | 61.2 |
| April | 62.7 | 21.5 | ..... | 19 212 | 60.9 |
| May | 65.63 | 21.1 | 0.6 | 20 334 | 62.7 |
| June | 67.12 | 22.8 | 0.9 | 23 288 | 63.9 |

TABLE 6.—CLEANING FILTERS.

| Month. | Number of filters cleaned. | Average duration of runs, in days. | Millions of gallons filtered during run. | Total Cost Per Million Gallons. | | | |
|---|---|---|---|---|---|---|---|
| | | | | Average cost of cleaning. | Average cost of pumping. | Average cost of office and laboratory. | Average total cost. |
| 1905. | | | | | | | |
| October | 13 | 49 | 146 | $0.63 | $0.90 | $0.43 | $1.96 |
| November | 12 | 45 | 136 | 0.58 | 0.94 | 0.53 | 2.05 |
| December | 5.25 | 51 | 172 | 0.40 | 0.98 | 0.54 | 1.92 |
| 1906. | | | | | | | |
| January | 4 | 69 | 233 | 0.36 | 1.38 | 0.74 | 2.48 |
| February | 2¾ | 104 | 332 | 0.33 | 1.14 | 0.59 | 2.06 |
| March | 4½ | 130 | 552 | 0.51 | 1.16 | 0.61 | 2.28 |
| April | 7 | 149 | 366 | 0.76 | 1.34 | 0.74 | 2.84 |
| May | 8½ | 130 | 298 | 0.79 | 1.01 | 0.59 | 2.39 |
| June | 11 | 125 | 297 | 1.05 | 1.54 | 0.59 | 3.18 |

The practical operation of the filters has developed one interesting point. The water which reaches them has been settled to an unusual extent. No filters of their type have been used in America with water settled to anything like the extent of the water which reaches them. This has the result of removing all the sand and silt from the water. The residual turbidity which reaches the filters is entirely of clay, and most of it is in an extremely fine state of division. The water often or usually does not contain particles of a size to form at the surface of the sand the sediment layer usually obtained in the operation of sand filters. The clay particles penetrate the sand to a considerable depth, and gradually fill up

the pores in the upper part of the sand layer to a depth of 2 or 3 in. Others go deeper and are deposited in the lower part of the sand layer, while still others go entirely through the filter and appear in the effluent. This condition results in an abnormally long period between scrapings, and in soiling the sand to a most unusual depth. These conditions were fully indicated in the experiments made by Mr. Hardy and Mr. R. S. Weston, under the direction of the late Colonel Miller, and experience in the practical operation of the plant has fully demonstrated the correctness of these experimental results and of the deductions made from them at the time.

The use of coagulant would change this and make the conditions more nearly normal, because the suspended matter in the applied water would be reduced in amount and changed in character, being in the form of a loose floc, capable of being stopped at the surface layer, and thus forming a normal sediment layer.

The plant will cost, complete, less than $3 400 000, and 5% interest and depreciation upon this sum is $170 000 per annum; or, for an average use of 67 000 000 gal., about $7 per million gallons. Adding this to the operating expenses, the total cost of filtering is about $9 per million gallons. As the Government pays an unusually low rate of interest on the money that it borrows, the actual cost is less than this amount.

### As to the Proposed Preliminary Treatment of the Water.

Potomac water is substantially free from dissolved coloring matter. It has sufficient alkalinity to allow the reasonable use of coagulant. In hardness it is a fairly soft water, ranging from 58 to 125, and averaging about 93 parts per million, according to the computation of Mr. R. S. Weston.

The sewage pollution, which is believed to have been a material element in producing typhoid fever in the city, is the most important characteristic of the water, from the standpoint of public health, while the suspended matter or turbidity is that quality of the water which makes the greatest impression upon the public.

The filters as constructed should easily remove the objectionable results of the sewage pollution, so as to make the water entirely satisfactory from a hygienic standpoint. It is clear that they will not always be able to produce a water free from turbidity.

As now arranged, it will be necessary to operate them without coagulating, and to produce as good an effluent as possible in that way.

*Consumption.*—An important element in the results that can be obtained in this way is the consumption of water. At the present time Washington is using more than 200 gal. per capita per day. A considerable quantity of water is used in public buildings, corresponding to manufacturing uses in other cities, but, after making all possible allowance for every use, the only conclusion that can be drawn is that a large part, probably fully one-half of all the water supplied, is wasted through leaky pipes and fixtures, and without benefit to anyone. The measures to be taken to restrict this waste and reduce the consumption to a quantity approximating the actual requirements are well known to water-works men. It requires only the necessary courage and determination, on the part of those who make the laws and are responsible for their enforcement, to carry out the reform and reduce the consumption to a reasonable amount. If this were done, and if the use of water were reduced to 50 000 000 gal. or less per day, there would be a good prospect of always delivering water substantially free from turbidity.

This could be done, because, in the first place, the rate of filtration would be low. In the second place, the frictional resistance of the aqueduct would be small, and the water in the reservoirs could ordinarily be at the highest permissible levels, and the sedimentation obtained would be considerably more complete than with a larger consumption; but, most important of all, it would be possible to close the intake at Great Falls in times of exceptional turbidity of the river water, and maintain the supply from the reservoirs, which would be large enough to serve for such lengths of time as extreme turbidity lasts. In this way, the average amount of suspended matter in the water taken for treatment would be very greatly reduced.

With the consumption at or near 75 000 000 gal. per day, the full capacity of the aqueduct, it is impossible to carry the reservoirs entirely full, owing to the frictional resistance in the aqueduct; and, with the reduced quantity of water in the reservoirs and the increased consumption, it is entirely impossible to maintain the supply during the longer periods of turbid water which occur in winter and spring. Under these conditions, therefore, even with the best

management, there will be times when effluents with seriously objectionable turbidity will be produced.

To increase the quantity of the supply beyond 75 000 000 gal. on the present basis may be regarded as an impossibility, as this figure represents both the capacity of the aqueduct and substantially the capacity of the filter plant, although both could be forced somewhat beyond it for a few days in case of emergency.

*Coagulation Works.*—As coagulation works have always been regarded professionally as essential, a brief consideration of the best location and arrangement of such works may be proper.

*Location.*—Works should be located on the line of the conduit below the Dalecarlia and above the Georgetown Reservoir. The application of coagulant at this point would be more advantageous than at Great Falls, and the Distributing Reservoir is better adapted to receiving the precipitate produced by it than either of the other reservoirs.

*Arrangement.*—The best arrangement of apparatus for applying the coagulant would be substantially that recently installed at St. Louis, namely, to allow a constant unmeasured stream of water to flow through dissolving tanks on its way to the point of application. Weighed quantities of solid coagulant would be placed in the boxes at short intervals, according to requirements.

*Cost.*—The cost of constructing the necessary works for adding coagulant would be very small, probably not more than $5 000. The cost of operation would be greater, amounting, as was first estimated, to an average of 50 cents per million gallons for all the water treated throughout the year, although varying considerably in different years with the amount of turbidity. The cost of operation would not be increased by this amount, for the coagulation would clarify the water to such an extent that longer runs could be obtained on the filters, and the cost of cleaning them would be materially reduced.

*Improvements in the Georgetown Reservoir.*—In connection with coagulation, the Georgetown Reservoir should be reconstructed and furnished with a concrete bottom, laid so as to drain to waste outlets to allow the considerable quantities of sludge, deposited as the result of the coagulation, to be easily and cheaply removed. It should also be baffled, in order to increase its efficiency as a sedi-

mentation basin. These improvements would cost about $100 000. Neither the Dalecarlia nor the Washington City Reservoir is suitable for use as a coagulating basin, as their bottoms and location do not permit of an arrangement for the economical disposal of sludge.

*Increasing the Capacity of the Plant.*—With these improvements carried out, a comparatively small further improvement would put the plant in such shape that it could be forced to a considerably greater capacity. A pumping station at Dalecarlia Reservoir, arranged to lift the water 5 or 6 ft. could be built at one side of the present channel, and without interfering with the regular use of the works. This would increase the hydraulic slope on both ends of the aqueduct system, so that 100 000 000 gal. per day would pass through it. With the coagulation of all very turbid water, it would be perfectly safe and proper to operate the filters at a rate of 4 000 000 gal. per acre, at which rate the above-mentioned quantity could be treated. The pipes and connections at the filters throughout are sufficient for the treatment of this quantity. There is, therefore, a possibility of increasing the capacity of the plant by one-third at a comparatively small expense.

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# PAPERS AND DISCUSSIONS.

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## STEAM LOCOMOTIVE AND ELECTRIC OPERATION FOR TRUNK-LINE TRAFFIC— A COMPARISON OF COSTS AND EARNINGS.

By Joseph Mayer, M. Am. Soc. C. E.

To be Presented November 21st, 1906.

The only adequate motive that will lead to the change from steam to electric operation is a large return on the investment required. The return on this investment is the increase in net earnings which is the result of the change. For finding this increase, the probable future earnings, if steam locomotive operation is continued, must be compared with these earnings if electric operation is introduced. The comparison to be made is not one of present net earnings from steam locomotive operations with future net earnings from electric operation; both terms of the comparison are future earnings. On all lines with heavy local passenger traffic, where steam locomotive operation is maintained, parallel interurban electric roads will be built which will take from the steam roads two-thirds or more of the local passenger traffic. This has already happened on many roads by the competition of the expensive and slow direct-current trolley roads. The severity of this competition

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will be greatly increased by the construction of much cheaper single-phase roads, which permit much higher speeds and larger cars and trains, without the use of the expensive and troublesome third rail and rotary converter sub-stations.

Greatly reduced passenger earnings with future steam locomotive operation, therefore, must be compared with the probable earnings accompanying electric operation.

Experience on interurban electric roads has shown that small trains or single cars can be run cheaply with many stops, and at higher speeds than is financially practicable with steam locomotives, and that a large increase of local passenger earnings is the result. If electric operation is introduced on the present steam roads, it must, to gain the fullest possible advantage, be generally accompanied by a great change in the number and size of trains, their speed, and the number of stops. The cars for strictly local passenger traffic must, like the present interurban electric cars, wherever practicable, run through the streets of the urban centers of population, so as to give continuous service without change of cars, and to take the passengers, as nearly as possible, from their starting point to their destination. Fares of about 1½ cents per mile have been found by experience most profitable for the kind of service given by interurban roads. They will probably be most profitable where similar service is attempted on the present steam roads.

A surprisingly large amount of local passenger earnings per head of accessible population has been secured by interurban electric roads, and has never been approached by steam roads. The present local passenger service of the steam roads, in view of the results obtained by interurban electric roads, is entirely antiquated and utterly inefficient. Dwindling local passenger earnings are the inevitable result of persistence in present methods. The cost of electric operation which must be considered, therefore, is that for the new trains or cars, at the new speeds, with the new number of stops; and not that of electrically operating trains of the number and size, and with the speeds and stops which have proved most economical with steam locomotives. On all roads with large local passenger traffic, the increase in passenger earnings which will be secured by the changes in method of operation taught by the experience of interurban electric roads is the most important

gain. The increase of local passenger traffic will greatly reduce all costs per passenger-mile, it will increase the total investment required but little, and will thereby reduce the interest charges per passenger-mile, as compared with those with a smaller traffic. The profit per passenger-mile needed to make the new investment a promising one is reduced nearly in the same ratio as that of the increase of traffic.

With steam locomotives, the heaviest through passenger trains cannot be run at the highest present passenger-train speeds. The capacity of the boiler that can be fired by one man and accommodated on one locomotive is limited, and has been closely approached in the largest present engines. Several steam locomotives cannot be controlled by one man at the head of the train. Fast trains with several steam locomotives, therefore, are not practicable. With electric operation, the heaviest passenger trains can be run at the highest speeds, and several locomotives may be used safely and economically on fast trains by means of multiple-unit control. The heavy, partially balanced, reciprocating parts of steam locomotives, which, at highest speeds, cause violent lateral swaying and vertical hammer blows on the track, and thereby greatly increase the cost of maintenance of way, are absent in electric locomotives. At the highest speeds the economy of steam locomotives diminishes rapidly with increase of speed, that of suitable electric locomotives remains approximately constant. With electric operation, higher speeds, therefore, will probably be adopted for all through trains, and the length of the fastest trains can be increased when desirable. As regards the probable future amount of local passenger traffic with the new kind of service, the experience gained on interurban electric roads must be the guide. In view of these facts, a mere comparison of the cost of operating the present passenger trains with steam or electricity has only a remote bearing on the question whether a change to electric operation is advisable, and must lead to an entirely erroneous estimate of the net return from the required investment. The present size and number of trains, and their speeds and number of stops, are closely adapted to the capacity of the steam locomotive. Wherever this train service for local passenger traffic has come into competition with interurban electric roads, its inferiority, as regards capacity to secure traffic,

has been clearly demonstrated. It will be abandoned, therefore, at the same time as the steam locomotive. The best possible electric service must be compared with the best steam-locomotive service, to obtain any results of value. The investigation will naturally begin with a consideration of the conditions which govern the probable increase of local passenger traffic and earnings due to improved service, since this is known to be the most powerful factor in favor of the change to electric operation. The accessible present and probable future population along the line furnish the future earnings.

Commuters using the line twice a day give the largest earnings per accessible inhabitant. They are important mainly near large cities, where their number along a line may increase rapidly by improved service. In such situations no further argument is needed to prove the superiority of electric operation, and the transformation of such lines is going on at a rapid rate.

The opinion is more divided in regard to long-distance lines. If the population along such a line is considerable, exceeding 500 inhabitants per mile of line, within 4 miles on each side, there exists either a competing interurban parallel trolley line or one may be safely counted upon in the near future. The existing line is probably a direct-current line on which small cars run at moderate speed. This can, and probably will, be changed to a single-phase line on which large cars can be run at high speed. If it is favorably located, it will receive the bulk of the previous local passenger traffic of the parallel steam road and all the new traffic developed by the improved service. By a change to electric operation of the steam railroad before the parallel trolley road is built, the latter is made impossible unless the available traffic is very large or the steam railroad is unfavorably situated to secure it. If the competing electric road is already in the field, a fraction of the total local passenger traffic, largely depending in amount on the location of the two competitors and the quality of their local passenger service, will be obtained by the steam road by the change to electric operation. Statistics of earnings of interurban electric roads have shown that they amount to from $3 to $10 per inhabitant within 4 miles of the line, not counting those in a terminal city of more than 75 000 inhabitants. It is evident that the distribution of the

population along the line, whether it is mainly within 1 mile of the line or further distant, and whether it is in a terminal or at intermediate points, is important. The degree of prosperity of the population and the quality of the roads will greatly influence the amount of travel per inhabitant. The location of competing lines will often limit the accessible area. The present local passenger traffic on the steam road, without a present electric competitor, gives a further clue, together with the experience in regard to the amount of traffic which has been developed by interurban electric lines along steam roads of the same or different amount of local passenger traffic. Equal improvement in local service will probably produce a nearly equal percentage of increase in local traffic. A detailed study of all the pertinent local conditions along the line is required to ascertain the probable amount of local passenger traffic which will be secured by any proposed electric service on the existing steam road.

The increase in through passenger traffic due to the use of higher speeds and the greater comfort and cleanliness possible with electric operation will, in many cases, be large, especially until electric operation is adopted by the competitors. There will be a great loss in the through traffic of the steam road if the competitors are first in the change to electric operation. The percentage of increase in through traffic cannot be calculated, but a moderate estimate will be nearer the truth than entire neglect of this gain.

The possible length of slow-speed freight trains using one engine is now mainly governed by the largest permissible draw-bar pull, which, with ordinary freight cars, is about 50 000 lb. With electric operation and multiple-unit control, it will be practicable to operate from the head several locomotives distributed through the train. Long trains can thereby be used on heavy grade lines, and the traffic capacity of two tracks can be indefinitely increased. On lines of large traffic, the possibility of operating passenger and freight trains of any desired length, and thereby reducing train expenses per unit of traffic and increasing the traffic capacity of the road, becomes very important. With high voltage in the contact conductor this is possible without much increase in the cost of the transmission line. Since accuracy in the estimate of the value of these advantages of electric operation is not possible, a

conservative estimate, which is probably below the truth, must be made, and, to justify a change, it must be shown conclusively that the necessary investment will bring a large percentage of return.

Next in importance to the increase of passenger traffic which may be secured by the adoption of electric operation is the reduction in the cost of motive power. This reduction is large where coal is dear, and especially so where a cheap water-power is also available within reasonable distance. At Niagara Falls power can be secured in large quantities with the load factor which will be obtainable in the electric operation of long lines of present steam railways for from ¼ to ⅓ cent per kw-hr. If power is produced in large central stations along the line, by means of gas engines and cheap, inferior coal, it will cost about twice as much at a central station. In a modern steam-turbine station, under favorable circumstances, power with the load factor of about five-eighths, which is easily obtainable on a busy double-track line of about 50 miles which would be served by such a station, can be produced for 0.7 cent per kw-hr., inclusive of all charges for interest and depreciation of plant. The transmission to the point of consumption will be cheaper with power-stations distributed along the line than with one water-power station, as the distances will be less. Within 200 miles of Niagara Falls, and other equally cheap water-powers, there will be a material saving by the use of water-power. Electric operation, therefore, is at present most seriously considered near large cities where local passenger traffic is important, also where coal is dear, and where cheap water-powers are available. As regards the freight traffic, the problem appears to be much simpler, because the amount of traffic and the number and size of trains may possibly remain the same. Interurban electric roads, however, have begun to encroach on the freight traffic of the competing steam roads. As single-phase roads will be better suited for the running of trains than the present direct-current trolley roads, this competition will become more severe in the near future; it has been of such small importance in the past, however, that its future amount cannot be quantitatively estimated with the desired degree of accuracy. It is neglected, therefore, in the following calculations. On lines with large passenger traffic the freight movement is mainly carried on during hours of moderate passenger movement. This

fact greatly improves the load factor or the ratio between the average and the maximum amount of power used. If power is obtained from a water-power plant with practically an unlimited amount of water, its cost of production mainly depends on the maximum amount consumed at one time. Any power used at other times costs practically nothing. The cost of transmission is also governed by the maximum consumption. The addition to the cost of power and its transmission, due to the electric operation of the freight traffic, therefore, is small wherever the maximum amount of power needed is mainly determined by the passenger traffic. There is, therefore, a great difference between the cost of electrically operating a given freight traffic, considered as a separate problem, and the cost of electrically operating this same freight traffic on a line with a large amount of electrically-operated passenger traffic; the difference is greatest where water-power is used, but is important even with steam-power. The two traffics, freight and passenger, must therefore be considered together; and the cost of power and its transmission to the motors must be charged mainly to the traffic which can best bear it. It will be found profitable to operate either both by steam or both by electricity. If a large reduction in the cost of operating the freight traffic is secured by adopting electric operation, lower freight rates may be charged, where necessary, to secure the traffic. A great increase in freight traffic may thereby be the result of electric operation, making the lower rates the most profitable. The amount of future traffic, therefore, will depend indirectly on the new cost of operation. To determine the former, an approximate estimate of the latter must, therefore, be made. This leads to a consideration of the technical features of the problem. These features concern the electric motor cars and locomotives, the transmission system, and the central power-stations. These must all be adapted to the future amount and kind of traffic.

### Voltage and Kind of Motors.

It is now generally admitted by the most eminent electrical engineers that the use of direct currents, at 600 to 700 volts, for transmitting the power to the locomotives by means of a third rail is uneconomical for the heaviest traffic. Direct currents at 1 500 to 2 000 volts, and alternate currents of 10 000 to 20 000 volts, and a

suspended contact conductor, are advocated for this purpose. The Zossen experiments, near Berlin, Germany, with high-speed trains, confirm the conviction of a few years ago of the leading electrical engineers of Germany. They may be summed up as high-speed, and high-voltage alternate currents. At that time three-phase currents with induction motors were adopted. The single-phase motor has since been developed. The investigations which are now under way, in Sweden, in Switzerland, and in the United States and other countries, for ascertaining the best system of electrically operating the present steam roads, all assume as proven the necessity of higher voltage in the contact conductor from which the current is gathered by the trolley wheel or a sliding collector. The demonstrable savings in the transmission system, due to the use of high voltage for heavy traffic, are so large that they leave no doubt in regard to its adoption. The proof by experience that high-voltage alternate currents can be safely used in the trolley wire, the invention of suitable alternate-current motors, and the great reduction in the cost of electrically operating the heaviest traffic which is thereby obtainable, promise to make the electric operation of trunk lines under favorable circumstances very profitable. A discussion of this subject a few years ago—before these events—had convinced the most competent engineers that the electric operation of trunk lines, with enlarged street-railway apparatus and the then usual voltages, is not profitable.

For the problem under consideration, the most important transformation of an ordinary steam railway with freight and passenger traffic into an electric road is that of the Valtellina Railway, a branch of the Rete Adriatica. This branch, near Lake Como in North Italy, is 66 miles long; it has a large passenger traffic, a convenient water-power, and is in a country of high coal prices, all factors very favorable to electric operation. It has been in successful operation since September, 1902. Three-phase current, at 20 000 volts, is produced directly by the dynamos in the water-power central station situated on the line. This is sent to transformer stations on the line where it is reduced to 3 000 volts. This is carried by two suspended trolley wires and the rails to the locomotives, where it is used by three-phase induction motors, which can be connected either singly or two in cascade for two economical

speeds. Regulation for all other speeds is obtained by water rheostats. The main objections to this system are the double trolley wire, which makes very high voltage difficult to handle, and the poor economy at all speeds except two. The double trolley wire can be avoided by the use of single-phase current, and good speed regulation can be secured by the use of variable voltage obtained from transformers with a variable ratio of transformation.

A suitable single-phase motor was unknown a few years ago. Several such motors are now available. The motors extensively used on interurban trolley lines are: in Europe, the Winter Eichberg motor, of the Allegemeine Elektricitäts-Gesellschaft, of Germany; and, in America, the Lamme motor of the Westinghouse Company. Neither of these motors has yet been made in sizes large enough for building four-motor locomotives for the heaviest present trains. Such motors should have a capacity of about 500 h. p., and should be able to carry 50% overload for a limited time. Their size must be such that they can be placed on a locomotive of moderate, rigid, wheel base. The largest motors thus far constructed by the Westinghouse Company are of 250 h. p., and two locomotives, each with four motors, are required for the heaviest freight trains or the fastest through passenger trains. These, however, can be operated by one man by means of multiple-unit control, and the main objections to the use of several locomotives on one train are thereby removed. These locomotives use high-voltage alternate currents, and have excellent speed regulation, giving practically uniform efficiency at any considerable speed, two advantages which far outbalance, especially for trunk-line traffic, their inferiority in other respects. This latter may be summed up as great weight per unit of power, limited capacity, high cost, and only moderate efficiency at any speed.

By the use of high-voltage alternate current on the locomotive the cost of the current transmission plant is much reduced, and the power losses in it are greatly diminished; the converter substations, with their large power losses, are either entirely saved or replaced by a far smaller number of much cheaper transformer stations with small power loss. The total result, for trunk-line traffic, is a great reduction in cost of construction, maintenance and operation, and some saving in the amount of power needed at

the power-station. The only commercial experience with alternate-current operation for moderately heavy traffic is with the three-phase locomotives of Ganz and Company on the Valtellina Railway. Their system has recently been adopted for the operation of the Simplon Tunnel. At present, the preponderance of theoretical argument is strongly in favor of single-phase currents for the operation of roads of varied and heavy traffic. The Swedish Government Commission, investigating the subject of electric traction for their steam railways, assumes this question as settled, and limits its investigation to various single-phase motors. In the experiments in Switzerland by the Oerlikon Company single-phase motors are also used.

Westinghouse single-phase locomotives have recently been adopted by the New York, New Haven and Hartford Railroad for the four-track line from New York to Stamford, and by the Grand Trunk Railway for the Sarnia Tunnel and approaches. It is evident that the tests with these locomotives have convinced the responsible officers of these companies that suitable single-phase locomotives can be constructed. For the steam railway from London to Brighton, England, single-phase operation has recently been decided upon. For the Pennsylvania line from Camden to Atlantic City, with a similar kind of traffic, direct-current operation has been adopted. So much practical experience has been obtained with direct-current operation with the kind of traffic on these two roads, which consists of frequent small trains, that the results which can be achieved by it are accurately known. The adoption of single-phase operation for the London-Brighton line is clear proof that its theoretical advantages, even in a field which has in the past been considered especially that for direct-current operation, must be considerable, because, in the opinion of the responsible officers, they succeeded in overcoming the advantage of extensive past experience with direct-current operation of similar traffic.

Schuler and Steinmetz have developed the repulsion-induction motor for single-phase alternate currents, but no tests with such motors of large sizes or locomotives containing them have been made, as far as known to the writer. Another method of using the power received from the contact conductor, in the shape of high-voltage single-phase current, is the Ward Leonard system.

The current is transformed to lower voltage, then, by means of an induction motor and a direct-current generator, into direct current, which is used in direct-current motors. This system is not suitable for single cars, but can be used on electric locomotives, and gives excellent and economical speed regulation. Its complication, moderate economy, inevitably high cost, and great weight, are its serious drawbacks.

All the single-phase motors mentioned have a commutator, and can also be operated with direct current. This last feature is valuable during the present transition. There is no commercial experience with single-phase locomotives able to handle trunk-line trains. No convincing proof can be furnished in regard to their exact cost of maintenance. There are, however, good reasons to believe that it will be less than that for steam locomotives of equal power.

At present, single-phase locomotives promise the simplest and cheapest method of operating large trunk-line trains. The following estimates, therefore, assume their use. For certain kinds of traffic, direct-current motors with much higher voltage than that used at present will probably be used extensively in the future, but they are not considered in the following. Three-phase induction motors may also continue to be used, but will not be considered here.

## Power Transmission.

The motors receive the current through a transmission system from one or more central power-stations. The transmission system, where the source is a water-power central station feeding a long line, will consist of the high-tension lines; the transformers, located in stations along the line, for reducing the pressure; and the contact lines on the side of, or over, the center of the tracks, either with or without feeders. Where heat power-stations are used, they will be at favorable points along the line, where water and coal are cheap, at intervals varying with the amount and kind of traffic and type of machinery used. Where favorable sites for power-stations can be found at distances of from 40 to 60 miles, 20 000-volt, single-phase current can be produced directly at the dynamos and sent to the locomotives without transformation; or lower voltage and shorter distances may be used, especially where the traffic is large and con-

sists of numerous units of moderate size. The use of the highest practicable voltage is especially desirable with very large but infrequent trains.

As a very high and dangerous voltage must be used in the suspended conductor, it is essential to suspend it in such manner that it will never come down. Trolley wires sometimes break and fall. Their method of suspension, therefore, is acknowledged to be inadequate. To prevent their falling, they are suspended from either one rope or wire immediately above, or from two ropes or wires in inclined planes. These carriers are of steel, and have considerable deflection between supports. Where only one rope is used for supporting a 000 or 0000 grooved copper wire, the strongest winds normal to the line will deflect to the leeward the originally vertical plane, containing the carrier, the suspenders and the trolley wire, so that it forms an angle of about 45° with the vertical. In this position, an ordinary trolley wheel leaving the wire while running at high speed would often strike the suspenders connecting the trolley wire and carrier. This would break the suspenders and give a violent jerk to the wire. It might thus break it and cause its fall. The ordinary trolley wheel, therefore, is not safe at very high speeds. A rolling contact, however, is desirable in order to diminish the wear on the trolley wire and on the collector. On the Valtellina Railway, with maximum speeds of about 50 miles per hr., long brass rollers with roller bearings have proved most satisfactory. This line has two trolley wires not suspended from ropes. On other roads sliding bows are used successfully. It is important that the point of contact should travel along the bow, as there will be rapid wear if this is not the case. To secure this, the trolley wire is not quite parallel with the track, but runs alternately to the right and left. With the high speeds of trunk-line trains and the very high voltages in the trolley wire, the greatest possible caution appears to be desirable.

To give more rigidity to the trolley wire, it is put under tension. This tension, however, varies greatly with changes of temperature. The suspenders are made stiff to prevent the rising of the wire with the passing of the sliding bow or roller. With a high voltage, the insulators are expensive and the leakage is considerable. Where a railway has great traffic, and can obtain money

at 4%, a substantial structure having small cost of maintenance becomes more advantageous than a short-lived, cheap, wooden structure. The timber poles of interurban trolley lines, therefore, are avoided, and the carrying ropes for the trolley wires are supported on steel bridges spanning the tracks, with steel towers at each side. With such bridges, long spans are more economical than short ones. With long spans, the vertical sag of the rope carrying the trolley wire must be considerable at the highest temperature. The wind will then blow the trolley wire out of reach of a sliding bow of moderate length. In this case, therefore, a trolley wire carried by a single rope is not satisfactory. It must be carried by two ropes in inclined planes meeting at the wire.

A satisfactory contact conductor which will be safe at the highest train speeds is one of the main problems to be solved before electric trunk-line operation can become a complete success.

The method thus far followed, in designing a new trolley wire suspension, has been empirical. The size of the wire and the number of supports have been increased, but no attempt has been made to calculate the effect of these changes on the strains produced in the contact wire by the sliding bow and the changes of temperature. A theoretical solution of this problem has been attempted in "The Mechanical Theory of the Contact Conductor for High-Speed Trains," which, to avoid interruption of the main argument, is introduced as an Appendix to this paper. It is evident that the subject under discussion cannot be treated exhaustively within the limits of a paper.

## Amount and Kind of Traffic.

What is here attempted is to show by means of a single instance, which is typical of a great many others, what financial results may be expected from the change from steam to electric operation of trunk lines. The instance used is the Lake Shore Railroad from Buffalo to Cleveland. The writer's information in regard to present conditions is derived from the published report to the stockholders for the year 1905. This report refers to the whole system. The cost of steam locomotive operation of the assumed amount of traffic on the selected part of the line can be inferred from the published data with a fair degree of accuracy. For the purpose of this argu-

ment, an approximate estimate of the present amount of passenger and freight traffic is sufficient.

The number of passenger trains at present is given in the time-tables. There is in existence a competing parallel electric road which would undoubtedly be improved if steam locomotive operation were maintained. The local passenger traffic, which has already suffered severely from this competition, would decrease still further. There are now approximately 28 daily passenger trains going over the line, 4 being local trains. The probable future traffic with steam locomotive operation is estimated at 26 daily trains for through passengers and 2 accommodation trains for local passengers. The average number of cars per passenger train is estimated at 8 and the earnings per passenger-train car-mile are estimated at 24 cents. This gives, for steam locomotive operation, passenger-train earnings of $3 590 000. This includes $3 333 000 from through traffic and $257 000 from local traffic.

### Increase in Passenger Traffic and Earnings.

The tracks are very crowded with traffic, and it is believed that it would not be expedient to run single cars or cars with trailers. The traffic for the shortest distances will probably generally remain with the present competing line. By establishing frequent fast local trains, the passenger traffic for medium distances can be secured. The combined population of the two terminals is about 900 000, that along the line is about 180 000. It is estimated that, by the service hereafter described, the local passenger earnings can be increased by $540 000, or $3 per head of population along the line. The increase in through-passenger-train earnings is estimated at 20% of the present earnings. The future loss in local passenger traffic by improved service on the competing electric road, if steam locomotive operation is maintained on the Lake Shore, is estimated at $123 000.

| | |
|---|---|
| The total difference in future passenger-train earnings between electric and steam-locomotive operation, therefore, is 20% of 3 333 000, or | $667 000 |
| Increase in local passenger earnings | 540 000 |
| Loss in local passenger earnings avoided | 123 000 |
| | $1 330 000 |

Recently, it has been the policy of steam railway companies to buy the competing parallel electric roads. By such purchase and the consequent removal of competition for the local traffic, passenger fares can be maintained, which give a larger profit from the local passenger traffic of the two lines than would be obtainable by them when competing with each other and each lowering the fares for the purpose of securing a larger proportion of the total traffic. This increase in profit can be divided among the two companies, and the change of ownership can thereby be made profitable to both.

If the steam railway is electrified before the purchase of the competing electric line the prospective earnings of the latter are much reduced. This will correspondingly reduce the purchase price. The prospective loss of earnings due to the inferiority of steam railway operation can only be avoided by the introduction of electric operation, because when the steam railway purchases the competing electric road, the price includes the capitalized value of this loss of earnings. The avoidance of this loss, therefore, is one of the gains secured by the electrifying of the steam road even if the latter afterward buys the competing electric road.

### Present and Future Trains.

At present there are, approximately, 28 passenger trains of eight cars, or 224 passenger-train cars, going over the line per day. These could not be materially reduced in number, in spite of decreased local traffic. Of these cars, 208 are in through trains. With 20% increase in through passenger-train earnings, 250 cars would be required for the through trains. For the $540 000 increase in local passenger earnings, with earnings of 24 cents per car-mile, 34 cars per day going over the line would be required. This gives 50 cars per day for local traffic, or a total of 300 cars per day for the whole passenger-train traffic.

The future traffic can be provided for by an average of 22 daily trains of 9 cars and an average of 21 daily trains of 5 cars, giving a total of 303 cars going daily over the whole line. In reality, the number of trains and of cars per train would vary with the seasons and, on different parts of the line, with the density of population along the line. As the increase in passenger traffic will be greatly affected by the schedule speeds, and as high-speeds can be

secured at moderate cost by electric operation with a cheap water-power, it will be advantageous to increase greatly the average train speed. An average increase of one-third over present speeds has been assumed in the following calculations. The through trains of 9 cars, therefore, should have a schedule speed of from 50 to 60 miles per hour, according to the number of stops. The 5-car trains should have a speed of from 30 to 45 miles per hour with stops from 2 to 6 miles apart.

### Capacity and Cost of Electric Motive Power.

The 9-car train would weigh, with locomotives, 500 tons. The 5-car train, with 2 motor cars, would weigh 250 tons.

Two 1 100-h. p. electric locomotives would be required for the long trains, and three 500-h. p. motor cars would be needed for the short ones. The horse-power here given is not the commercial rating, but the average capacity of the motors in service.

The present freight traffic is estimated at 34 revenue and 3 work trains per day going over the whole line. It is assumed that the amount of freight traffic will not be affected by the method of operation. The average weight of the freight trains is estimated at 1 600 tons. The trains going east are much heavier than those going west. Two 1 100-h. p. locomotives would be needed for the heaviest trains. Two such locomotives can haul a train of 2 200 tons at 36 miles an hour over a level, straight track. If an average of two locomotives is used per train, much higher speeds can be maintained than with the present steam locomotives. Assuming 35 000 revenue train-miles per year per electric passenger locomotive, two-thirds of this number per electric motor car, and 25 000 per electric freight locomotive, which allows for the fact that each train is assumed to have two or three motor units, there will be required, for the above traffic, 42 passenger locomotives, 90 freight locomotives and 60 motor cars.

From various data, the following safe estimate of the cost of this motive power equipment is obtained:

| | |
|---|---|
| 42 passenger locomotives, each 1 100 h. p., at $33 000 | $1 386 000 |
| 90 freight locomotives, each 1 000 h. p., at $30 000 | 2 700 000 |
| 60 motor cars, each of 500 h. p., at $18 000 | 1 080 000 |
| Total | $5 166 000 |

### Passenger Cars and Locomotives Saved.

The present passenger traffic requires 14 960 000 car-miles, or, with 45 000 car-miles per car, 332 cars. The future traffic will give 70 000 car-miles per car. It will require 76 032 000 car-miles per year, not counting the motor cars, of which there are 3 in each 5-car train. There will be needed 229 passenger cars; and 103 passenger cars will be saved. From data in the published report of the Lake Shore Railroad it is inferred that 150 locomotives will be saved.

The value of the rolling stock saved is estimated at $2 286 000
The net cost of new rolling stock, therefore, is.....$5 166 000
Less..... 2 286 000

$2 880 000

### Amount and Cost of New Track Required.

The length of track at present on the 183 miles of line between Buffalo and Cleveland is estimated at 550 miles. The larger passenger traffic will require additional track. The necessary new track is estimated at 50 miles, its cost at $1 000 000.

For this traffic there would be required seven transformer stations having a total capacity of 45 000 kw., costing, complete, $8 per kw., or $360 000. For each track is needed a 1¼-in. suspended contact rod with suspenders 12 ft. apart; for each rod, one 1-in. carrying rope of 40 tons ultimate strength, with 7 ft. maximum vertical sag and 350-ft. spans. For every 350 ft. of line one overhead bridge will span the tracks and be supported between two steel transmission towers. The towers are required to carry the high-tension lines and feeders. To reduce to 4% the average loss in the secondary circuit, with maximum traffic and with 15 000-volt, 25-cycle, single-phase current, two No. 0, B. & S. gauge, copper feeders are required for each pair of tracks. The contact rods should be in insulated sections 2 miles long, the ends and center of the sections connected to the feeders by circuit breakers, so that any section of the rods can be cut out in case of a short-circuit. The rails must be bonded and cross-connected to serve as a return circuit. On account of the low conductivity of the rods for

alternate currents, the transformer stations must be nearer together than if 0000, B. & S. gauge, contact wires are used with the same relay feeders. The contact rods carry for most of the distance but a small current, and the rail return circuit to the transformer stations is shorter than with contact wires. The secondary circuit with contact rods, therefore, has about the same self-induction as the longer secondary circuit with contact wire.

The cost of the secondary circuit, the towers along the line for the primary circuit, and the transformer stations, all per mile of track, will be approximately as follows:

| | |
|---|---|
| Supporting steel structure, insulators, circuit-breakers, etc. | $2 428 |
| Transformer stations | 600 |
| Contact rods and suspenders | 712 |
| Ropes | 608 |
| No. 0 feeders and accessories | 372 |
| Track bonds, etc. | 80 |
| Total per mile of track | $4 800 |

This makes the total cost, for 600 miles of track, $2 880 000.

The cost of steel erected is assumed to be 3 cents per lb.; that of concrete foundations, $8 per cu. yd.

### Power Transmission Towers.

Power would be obtained from Niagara Falls. Two lines of steel towers, each 25 miles long, would be required between Buffalo and Niagara Falls, at $2 000 per mile, and would cost $100 000. The cost of towers along the line is included in the cost of the contact line.

### Amount and Cost of Electric Power.

It will be shown in the following that a maximum of 42 150 h. p. will be needed at the primaries of the transformers in the transformer stations along the line. The average distance of transmission to these stations is 117 miles. If the average voltage received is 50 000, and the loss in transmission 15% of the power leaving the power-station, if the power factor is 85%, and if single-phase transmission is used, then the quantity of copper required for

the high-tension transmission line is approximately 5 100 000 lb. This copper costs, in place, with accessories, about 22 cents per lb. This gives for its total cost $1 122 000. An aluminum line would probably be cheaper. The amount of power needed for the trains given above is obtained as follows:

The train resistance for freight trains is estimated at 8 lb. per ton. This is intended to cover the small amount of power lost by the use of the brakes, which includes the net grade resistance on the nearly level line. The train resistance of through passenger trains is estimated at 18 lb., that of the local trains at 26 lb. per ton. This includes the power wasted by the use of brakes. The last estimate is based on running sheets assuming an acceleration of 1.2 ft. per sec. and a retardation by the brakes of 2.4 ft. per sec.

Power is used for lighting the trains, for the operation of the brakes, and for switching. These last three items are estimated at 15% for freight trains, 7½%. for through passenger trains and 5% for local trains.

If it is kept in mind that 1 h.p-day is equal to 23 760 ft-tons per day, the following formulas for the horse-power needed by the 37 daily freight trains averaging 1 600 tons, the 22 daily through passenger trains averaging 500 tons, and the 21 daily local passenger trains averaging 250 tons, each running over the 183 miles of line, are self-evident:

$$\frac{5\,280 \times 183}{23\,760} \times 37 \times \frac{1\,600 \times 8}{2\,000} \times 1.15 = 11\,073$$

$$\frac{5\,280 \times 183}{23\,760} \times 22 \times \frac{500 \times 18}{2\,000} \times 1.075 = 4\,328$$

$$\frac{5\,280 \times 183}{23\,760} \times 21 \times \frac{250 \times 26}{2\,000} \times 1.05 = 2\,914$$

$$18\,315$$

The tracks will be so crowded that the freight trains must run mainly during times of small passenger traffic. A load factor of two-thirds, therefore, can be easily secured. The maximum power required at the wheels of the motor units, therefore, will be $\frac{3}{2} \times 18\,315 = 27\,473$ h. p. The average efficiency of the electric locomotives and motor cars will be at least 70%; that of the low-tension transmission, at 15 000 volts, 96%; that of the step-down trans-

formers, 97 per cent. This gives an efficiency, from the primary of the step-down transformers to the wheels of the motor units, of $0.70 \times 0.96 \times 0.97 = 0.6518$ per cent. The maximum power required at the primary of the step-down transformers, therefore, is $\frac{27\,473}{0.6518} = 42\,150$ h. p.

The efficiency of the high-tension transmission is 85%, when the maximum power is transmitted. The total efficiency from the step-up transformer station to the wheels of the motor units, therefore, is $0.6518 \times 0.85 = 55.4$ per cent.

The maximum amount of power required at the secondary of the step-up transformers, therefore, is 49 600 h. p., or approximately, 50 000 h. p. At $12 per h. p. this will cost $600 000 per year.

## Cost of Maintenance and Depreciation of Electric Locomotives, Motor and Passenger Cars.

The cost of maintenance and depreciation of the electric locomotives is not known. It is estimated at 10 cents per train-mile, or $3 500 per passenger locomotive and $2 500 per freight locomotive per year. This is probably excessive. The cost of maintenance and depreciation of motor cars is estimated at 8 cents per train-mile, or $1 867 per motor car per year. The cost of maintenance and depreciation of passenger cars is estimated at 1.4 cents per car-mile.

With steam-locomotive operation, approximately 224 cars go over the whole line daily. The future traffic will require 303 passenger-train cars to run daily over the whole line. Of these, 63 will be motor cars and 240 other passenger-train cars, an increase of 16. This represents 1 068 800 car-miles per year. The increase in cost of maintenance of passenger-train cars, exclusive of motor cars, therefore, is $15 000 per year. The cost of train service and motive power is estimated as follows: First, for the traffic with steam-locomotive operation.

*Cost of Steam Locomotive Power.*—The Lake Shore Railroad report for 1905 gives the cost of locomotive power per locomotive-mile for the whole system as 32.07 cents. The revenue train-mileage is 15 901 016. The locomotive mileage is 25 741 488.

The cost of locomotive power per revenue train-mile, therefore,

is $\frac{25\,741\,488}{15\,901\,016} \times 32.07 = 55.28$ cents, say, 55 cents. The 28 passenger trains and 34 revenue freight trains per day represent 4 140 000 train-miles per year. The total yearly cost of locomotive power on the line and for the traffic here considered, therefore, is $2 277 000. The trains are larger on this line than the average train of the system; for this reason this is probably an underestimate.

*Cost of Electric Locomotive and Motor Car Service.*—For electric operations the cost of motormen for passenger trains is estimated at 3 cents, and for freight trains at 6 cents, per train-mile.

*Cost of Train Service.*—The other trainmen on the freight trains will cost considerably less with electric than with steam-locomotive operation, owing to the higher train speeds practicable with the former. The new passenger trains will have about one-third more cars running daily over the whole line and one-third greater speed; the cost of car service, therefore, will remain about the same.

*Cost of Maintenance of Way.*—In the opinion of high authorities, the cost of maintenance of way is mainly caused by the steam locomotives. The excessive weights on the drivers of the largest locomotives, especially at high speeds, are very severe on the track. The imperfectly balanced drivers and the heavy reciprocating parts produce vertical hammering and lateral swaying. The electric locomotives have no heavy reciprocating parts, and the weights on the drivers are very moderate. The cost of maintenance of way will probably be largely reduced. The amount of this reduction is unknown, and is here neglected.

*Summary of Comparison of Costs.*—The results of these considerations are summarized in the following tabulation:

Estimated future daily trains on 183 miles of line from Buffalo to Cleveland with steam-locomotive operation:

28 passenger trains of 8 cars,
34 revenue freight trains,
3 work trains.

| | |
|---|---|
| Estimated future passenger earnings with steam-locomotive operation | $3 467 000 |
| Estimated increase of passenger earnings by electric operation | 1 330 000 |
| Future passenger earnings, with electric operation | $4 797 000 |

Future trains with electric operation:

34 revenue freight trains,
3 work trains,
22 passenger trains of 9 cars,
21 passenger trains of 5 cars.

Cost of new plant for electric operation:

| | |
|---|---|
| 50 miles of tower lines | $ 100 000 |
| 5 100 000 lb. of copper for high-tension lines, in place, with switches, lightning protection, etc. | 1 122 000 |
| Overhead contact lines, sub-stations, and track bonding, etc., for 600 miles of track | 2 880 000 |
| 50 miles of new track | 1 000 000 |
| | $5 102 000 |
| 42 passenger locomotives of 1 100 h. p. at $33 000 | $1 386 000 |
| 90 freight locomotives of 1 000 h. p. at $30 000 | 2 700 000 |
| 60 motor cars of 500 h. p. at $18 000 | 1 080 000 |
| | $5 166 000 |
| 150 steam locomotives and 103 passenger cars saved | 2 286 000 |
| Net cost of new rolling stock | 2 880 000 |
| Total | $7 982 000 |
| Contingencies | 798 000 |
| Total new investment | $8 780 000 |

Cost of electric operation of future traffic:

| | |
|---|---|
| Current, 50 000 h. p., at $12 | $ 600 000 |
| Maintenance and depreciation of 50 miles of tower lines, 3% | 3 000 |
| Maintenance of copper, etc., for high-tension lines, 1½% | 16 800 |
| Maintenance and depreciation of 600 miles of contact line and sub-stations, 4% | 115 200 |

| | |
|---|---|
| Maintenance and depreciation of electric locomotives, 10 cents per train-mile | 394 100 |
| Maintenance and depreciation of motor cars, 8 cents per train-mile | 112 224 |
| Motormen of freight trains, 6 cents per train-mile | 148 296 |
| Motormen of passenger trains, 3 cents per train-mile | 86 170 |
| Increase in cost of maintenance of passenger cars | 15 000 |
| Total | $1 490 790 |
| Interest and taxes on cost of plant, 5% | 439 000 |
| | $1 929 790 |
| Cost of steam-locomotive power saved | 2 277 000 |
| Net saving | $ 347 210 |
| Increase in passenger earnings | 1 330 000 |
| Total gain | $1 677 210 |

This is 19.1% of the capital invested, and is in addition to about 4% interest counted among the yearly expenses. If the power were derived from four steam-turbine power-stations along the line, the stations with their machinery would cost about $3 200 000. The transformer sub-stations could be replaced by feeders. The power could be produced at the stations in the form of 15 000 or 20 000-volt, single-phase current. The saving in the cost of the transmission system would be about $1 200 000. The net increase in investment would be about $2 000 000.

The efficiency of transmission would be about 95%, and the total efficiency, from power-stations to wheels, $0.70 \times 0.95 = 66.5$ per cent. The average power required at the power-houses would be approximately 20 600 kw., its cost at the power-house would be approximately $60 per kw. per year, or $1 236 000, allowing 5% on the cost of the plant for interest and taxes.

The cost of water-power and of its transmission, amounting, with interest and taxes on transmission plant, to $680 900, would be saved. The net increase in yearly cost of operation and interest and taxes, therefore, would be $555 100. This would reduce the

yearly gain from electric operation to $1 142 200, or 10.6% on the investment. Adding 4%, as previously allowed, the total return on the invested capital would be 14.6 per cent. With the more expensive steam power, better financial results would probably be obtained with slower passenger trains, requiring much less power. It is apparent, therefore, that the electric operation of lines of similar amount and kind of traffic will be profitable even where no water-power is available. The density of population along the line, the degree of its prosperity, the presence or absence of a competing electric line, and the fare per passenger-mile determine the increase in local passenger traffic that can be counted upon. The amount of existing through passenger traffic on the line considered, and the intensity of competition for it, as well as the amount of the through passenger traffic on the competing lines and the fare per passenger-mile, determine the increase in through passenger traffic which will be the result of electric operation and the consequent improvement in the service. On all lines of large traffic, the increase in traffic capacity of a given number of tracks will give very valuable advantages which have been entirely neglected in this calculation.

### Alternate Estimate.

The adopted estimates of the increase of the passenger earnings are based on voluminous statistics of the amounts of passenger earnings secured by the interurban electric roads. These statistics can be found in various technical and financial periodicals of the last few years.

The writer was greatly surprised at the amount of new passenger traffic developed by these roads. Without knowledge of the results obtained by them, he would have considered excessive the estimates here given for the probable increase of earnings due to the introduction of electric operation. It would probably require a longer paper than that here submitted to convince those unfamiliar with the facts here referred to that the estimate herein adopted is conservative and will be more than confirmed by the actual results. Since this estimate will be accepted as reasonable by but few without the elaborate proofs which cannot here be given, it is desirable to show how a lower estimate of the increase in earnings will affect the rate of return on the invested capital.

Where Niagara Falls or other equally cheap power is obtainable it can be easily shown that the electric operation of a line with the traffic here assumed is advisable even with one-half the increase in passenger earnings above estimated. The reduction of $665 000 in passenger earnings, as compared with the foregoing estimate, would permit a reduction of one in the average number of cars per passenger train. The locomotives for the through passenger trains would then have to be of 1 000 h. p., and the local passenger trains would require, with a slight reduction of the schedule speeds, an average of 2 motor cars instead of 3. This would reduce the power required to 94% of the former amount. An equal reduction would take place in the required capacity of the transformers, and in the amount of copper in the high-tension lines.

The number of motor cars required would be reduced to 40. The reduction in cost of plant would be approximately as follows:

| | |
|---|---|
| Copper for high-tension line | $ 67 300 |
| Transformers | 21 600 |
| Motor cars | 360 000 |
| Electric locomotives | 126 000 |
| 20 passenger cars | 80 000 |
| | $654 900 |
| Contingencies 10% | 65 500 |
| Total reduction of cost of plant | $720 400 |

This gives the revised cost of plant as $8 059 600.

The reduction in yearly cost of operation would be as follows:

| | |
|---|---|
| Current | $ 36 000 |
| Maintenance of copper | 1 000 |
| Maintenance of sub-stations | 1 000 |
| Maintenance and depreciation of motor cars | 37 400 |
| Maintenance of passenger cars | 20 570 |
| Interest and taxes on cost of plant | 36 020 |
| Increase in net saving | $131 990 |

The new net saving by electric operation would be $479 200. If $665 000 is added, for the new increase of passenger earnings, the result will be $1 144 200 as the total gain by electric operation. This is 14.2% of the total investment. The total return on invested capital, inclusive of about 4% interest allowed among the operating expenses, therefore, is 18.2 per cent. This estimate will undoubtedly appear more reasonable to those unacquainted with recent results on interurban electric roads.

*Cost of Hauling a Car.*—It is of interest to compare the cost of hauling a freight or passenger car 1 mile by steam locomotive and by electric power. In this calculation it is fair to include the interest and taxes on the cost of the plant, because the stockholders of the corporation, who will govern the decision, are mainly interested in the question whether the cost of hauling, inclusive of the new interest charges, is increased or decreased.

It is found, by distributing the total cost of locomotive power among the number of revenue train-miles, that the cost per revenue train-mile is approximately 55 cents. If this cost is assumed to be the same for passenger and freight trains, there is obtained, with 8 cars per passenger train, 6.875 cents, as the cost per car-mile. This does not include the interest and the taxes on the value of the locomotive and tender. Taking their value to be $12 500, and estimating, from published data, the number of revenue passenger train-miles per locomotive at 33 000 per year, and taking interest and taxes at 5%, the interest charge per car-mile is equal to $\frac{12\,500 \times 0.05}{33\,000 \times 8} = 0.237$ cents. This gives for the total cost of hauling a passenger car 1 mile in a revenue train by steam locomotive $6.875 + 0.237 = 7.112$ cents. This includes the estimated share of the cost of switching and work trains.

The freight cars at present in use vary considerably in size. The writer has calculated the cost of hauling 1 mile a car weighing 70 tons when fully loaded, inclusive of the estimated share of the cost of the switching and work trains.

For the average train of 1 600 tons the locomotive and tender will weigh approximately 150 tons. The cost of hauling a train 1 mile is 55 cents, exclusive of interest and taxes. Taking 23 000 revenue freight train-miles per locomotive per year, the interest

and taxes per train-mile amount to $\frac{12\,500 \times 0.05}{23\,000} = 2.72$ cents; this makes the total cost of hauling a freight train 1 mile, including a proper share of the cost of the switching and work trains, 57.71 cents. The average train of 1 600 tons, inclusive of locomotive, contains 20.71 cars of 70 tons. The cost per car-mile, therefore, is $\frac{57.71}{20.71} = 2.788$ cents.

*Cost of Electric Haulage.*—For determining the cost of electric power at the motor car or electric locomotive there must be added to the cost at the power-house that of transmission. The cost of the transmission plant proportioned for receiving 50 000 h. p. and delivering at motor cars 39 575 h. p. is $4 102 000. The total cost of the delivered power, therefore, is as follows:

| | |
|---|---|
| 50 000 h. p. at power station..... | $600 000 |
| 5% interest and taxes..... | 205 100 |
| Maintenance of copper, etc..... | 16 800 |
| Maintenance of 50 miles of tower line.. | 3 000 |
| Maintenance of secondary lines and transformer stations ..... | 115 200 |
| Total cost at train of 39 575 h. p..... | $940 100 |

Cost per horse-power per year, $23.75.

Since the load factor is two-thirds, the horse-power-year contains $\frac{2}{3}$ of 8 760 h.p-hr. The cost of power per horse-power-hour used at motor car or locomotive, therefore, is 0.4067 cents.

The power required at the wheels for hauling 22 daily through passenger trains a distance of 183 miles was found to be 4 328 h. p. This includes the power required for switching, train lighting and the operation of the brakes. It does not include the power for the three work trains. The latter is $\frac{3}{37}$ of 11 073 = 898 h. p. In the calculation of the cost of steam power all the costs of power have been charged to the revenue trains. Following the same method, the cost of the power for the work trains will be charged to the cost of hauling the passenger trains. The cost of power per passenger train-mile becomes, therefore, $\frac{(4\,328 + 898) \times 24}{22 \times 183 \times 0.7} \times 0.4067$ = 18.11 cents. These trains have an average of 9 cars; the cost of

power per car-mile, therefore, is 2.012 cents. The costs incurred on the locomotive, per revenue train-mile, are 10 cents for maintenance and depreciation, 3 cents for motormen, 4.73 cents for interest and taxes, a total of 17.73 cents, or 1.97 cents per car-mile. This gives the total cost of hauling a passenger car 1 mile 2.012 + 197 = 3.982 cents. The schedule speed of this car is one-third greater than that of the car hauled by the steam locomotive. This higher speed increases the energy required about 25 per cent. The corresponding cost of steam-locomotive haulage at the slower speed was found to be 7.112 cents. Steam-locomotive haulage at the higher speed, if practicable at all, would cost more than twice as much as electric haulage.

It was found that it takes 11 073 — 898 = 10 175 h. p. to haul 34 daily revenue freight trains a distance of 183 miles. The cost of power per revenue train-mile, therefore, is $\frac{10\,175 \times 24}{34 \times 183 \times 0.7} \times 0.4067$ = 22.81 cents.

The costs per train-mile on the locomotive are:

Maintenance and depreciation, 10 cents; motormen, 6 cents; interest and taxes, 6 cents; total 22 cents.

The cost of hauling a 1 600-ton freight train 1 mile, therefore, is 22.81 + 22 = 44.81 cents. This is $\frac{44.81}{20.71}$ = 2.164 cents per car-mile. This includes the cost of switching and the operation of the brakes.

The speed is one-third greater than with steam locomotives; this reduces the cost of the train crews per train-mile. The corresponding cost of steam haulage at the slower speed is 2.788 cents. In the same manner the cost of hauling with electric power a passenger car of a 5-car train is found to be 5.09 cents. The schedule speed is one-third greater than for steam trains with the same number of stops. All items of cost that are the same with steam locomotives and by electric operation have been omitted in these comparative estimates.

## Conclusions.

Unless these calculations are greatly in error, it is evident that the electric operation of many steam railroad lines will be extremely

profitable, especially where the passenger traffic is large, where there are no existing parallel electric lines, and where cheap water-powers are available.

The writer is indebted to the General Electric Company for information in regard to the cost of single-phase motor cars and locomotives. This information, however, was received two years ago, and the prices given in this paper are based mainly on later published prices. All estimates of cost of electric plant and operation were intentionally taken very high. Future experience alone can determine the accurate costs of electric operation. The writer is convinced that the cost of electric operation here given is in excess of what it will prove to be upon actual trial. The figures given were chosen with a view of being able to prove from past experience with similar, though not identical, apparatus and plant that they are at least adequate. The cost of single-phase electric locomotives and motor cars will probably greatly decrease within a short time, and this will make possible a much better showing for electric operation.

For roads with small traffic, an entirely different and much cheaper contact line, and smaller and slower trains would be used. The results here obtained do not justify any inference either for or against the electric operation of such roads.

The arguments given in this paper are the result of the condensation and revision of several voluminous reports, by the writer, on this subject. After discussion, further details will be given on points which are contested, if the writer is able to do so.

Various estimates of the cost of electrically operating a given amount of either freight or passenger traffic have been published. The writer believes that the only way to obtain a correct answer to the question, Will electric operation pay? is to consider the problem as a whole, and to compare the probable increase in future net earnings, due to the changes and improvements in passenger service which become practicable and will be adopted with the introduction of electric operation, with the required new investment of capital. Wherever electric operation has been adopted, the gain in passenger earnings has been by far the most important factor in making the change profitable. The writer hopes that the discussion will bring forth valuable new information on various parts of the subject.

# APPENDIX.

## THE MECHANICAL THEORY OF THE CONTACT CONDUCTOR FOR HIGH-SPEED TRAINS.

No contact conductor is absolutely straight when the sliding bow passes over it. The latter, therefore, does not move in a straight line, but rises and falls alternately. There are two methods of keeping the contact conductor approximately straight. One consists in using a rod, of sufficient cross-section to resist the bending stresses to which it is exposed and avoid temperature stresses by means of expansion joints. The other method consists in using a wire under tension. This wire will be pushed up by the pressure of the sliding bow and then pulls down on both sides of it. If it is large, and especially if it is grooved and has an elongated cross-section, it has also considerable stiffness and resists some part of the pressure of the sliding bow by acting as a girder. The tension in the wire will vary greatly according to the temperature. The modulus of elasticity of a copper wire is about 20 000 000 lb. per sq. in.; the coefficient of expansion is 1 in 104 400 per degree Fahrenheit. If the temperature varies 140° there is $\frac{140}{104\,400} \times 20\,000\,000 = 26\,820$ lb. change in tension per sq. in. if the length of the wire remains the same. If the wire has always the same length, excessive strains at minimum temperatures can only be avoided by making the tension at maximum temperatures very small. With rope suspension and 300-ft. spans, the deflection of the wire, with changes of temperature, varies only about 1 ft. The length of the wire changes so little that this change is quite negligible, if the wire is taut in summer. This practically constant length of the contact wire is one of the serious drawbacks of rope suspension, as it greatly increases the variation in tension due to changes of temperature.

If the sliding bow moves rapidly up and down, its pressure on the contact conductor will vary greatly. It may become so great as to break the conductor, or may become zero and cause a separation accompanied by sparking. An investigation of these variations of pressure between sliding bow and contact conductor, therefore, is essential in making a rational design of either. The calculation is somewhat simpler with a contact rod acting only as a girder than with a wire acting as a tensile member and as a girder. For this reason the writer will begin with the former.

It will be assumed that a soft steel rod, $1\frac{1}{8}$ in. in diameter, is suspended from a rope by suspenders 15 ft. apart. This rod, be-

cause of its weight, will not hang straight, but in a waved line. The equation of its curve between two succeeding suspenders is:

$$y = \frac{P}{E\,I}\,\frac{l^3}{24}\left\{\frac{x^2}{l^2} - \frac{2\,x^3}{l^3} + \frac{x^4}{l^4}\right\}.$$

In this equation,

$P$ is the weight of one panel of rod = 50 lb.;

$E$ is the modulus of elasticity of the material = 29 000 000 lb. per sq. in.;

$I$ is the moment of inertia of the cross-section of the rod = 0.07862 in.;

$l$ is the length of the panel = 180 in.

The origin of co-ordinates is at the intersection of the suspender with the rod. First, it will be assumed that the sliding bow or roller which collects the current moves along this curve with a velocity of 80 miles an hour = 1 408 in. per sec., and the variation of pressure between contact rod and oscillating sliding bow will be investigated. If the time begins when the sliding bow passes a suspender, and if $x$ designates the distance of the point of contact from the same suspender, then $x = v\,t$, where $v$ is the velocity, in inches per second, and $t$ the time, in seconds. The current collector moves on the curve given by the equation:

$$y = \frac{P}{E\,I}\,\frac{l^3}{24}\left\{\frac{x^2}{l^2} - \frac{2x^3}{l^3} + \frac{x^4}{l^4}\right\}.$$

If $x$ is replaced by $v\,t$, then

$$y = c\left\{\frac{v^2\,t^2}{l^2} - \frac{2\,v^3\,t^3}{l^3} + \frac{v^4\,t^4}{l^4}\right\}, \text{ where } c = \frac{P}{E\,I}\,\frac{l^3}{24}.$$

Differentiating the equation twice gives:

$$\frac{d\,y}{d\,t} = c\left\{\frac{2\,v^2\,t}{l^2} - \frac{6\,v^3}{l^3}\,t^2 + \frac{4\,v^4}{l^4}\,t^3\right\}$$

$$\frac{d^2\,y}{d\,t^2} = c\left\{\frac{2\,v^2}{l^2} - \frac{12\,v^3}{l^3}\,t + \frac{12\,v^4}{l^4}\,t^2\right\}.$$

This gives, for $t = 0$, at the end of the span,

$$\frac{d^2\,y}{d\,t^2} = \frac{c\,2\,v^2}{l^2} = \frac{P}{E\,I}\,\frac{l}{12}\,v^2.$$

For $t = \frac{l}{2\,v}$ at the center of the span,

$$\frac{d^2\,y}{d\,t^2} = -\frac{c\,v^2}{l^2} = -\frac{P}{E\,I}\,\frac{l}{24}\,v^2$$

The expression, $\frac{d^2\,y}{d\,t^2}$, is evidently the acceleration of the vertical motion of the contact point of the current collector. This acceleration is produced by the resultant of the forces acting upon it. These forces are the downward pressure of the contact conductor,

the weight of current collector, and the upward pressure of the springs supporting the latter. The collector itself may be a spring of which only the part at and near the contact point moves up and down, so that the weight moving up and down is small; or it may be a roller, of copper or brass, which is rigid and moves up and down as a whole. The ends of the roller must be supported on springs for the purpose of reducing the weight moving up and down once in each span.

Past experience on trolley lines and on the Valtellina Railroad is strongly in favor of a rolling contact between the wire and the collector. The roller, however, is not practicable, as will be shown in the following, where the highest speeds and a contact wire carried by frequent suspenders are used.

With a contact rod a sufficiently light roller can easily be designed. If a roller having a weight of $w$ pounds, is assumed to be supported on springs sufficiently yielding not to transmit the rapid up and down oscillations to the frame below, then the force needed to produce the acceleration given above, for $t = 0$, is

$$F = \frac{w}{12 \times 32.2} \frac{d^2 y}{d t^2} = \frac{w}{12 \times 32.2} \frac{P}{E I} \frac{l}{12} v^2.$$

If $w = 25$ lb., and the values of $P$, $l$, $E$, $I$ and $v$ be the same as given above, all dimensions being in inches, then

$$F = \frac{25}{12 \times 32.2} \times \frac{50 \times 15 \times 1\,408^2}{29\,000\,000 \times 0.07862}, \text{ or}$$

$F = 42.19$ lb. For $t = \frac{l}{2\,v}$, which corresponds to the center of the span, $F = -21.1$ lb.

The meaning of these results is that at the suspenders, where the curve of the contact rod is convex above, the collector presses upward not only with the pressure which it exerts when it moves in a straight line, or is at rest, but with this pressure increased by 42.19 lb., due to its curved motion. At the center of the 15-ft. span the curve of the contact rod is convex downward. The pressure of the roller is reduced by 21.1 lb., due to the curvature of the rod. To avoid the separation of the collector and the contact rod, the pressure when at rest must be at least 21.1 lb. To allow for inaccuracy and leave a moderate minimum pressure to produce good contact, it should be somewhat larger, say 25 lb.

The radius of curvature of the rod at any point is approximately equal to $\frac{1}{\frac{d^2 y}{d x^2}}$. This gives, for the radius at the suspender, from the above equation of the curve, $r = 253$ ft., and for the center of the span, $r = 506$ ft. The variation of pressure between

the sliding bow and the contact rod might also be considered as the variation of the centrifugal force during the motion in a curve. The centrifugal force is

$$F = \frac{w}{g}\frac{v^2}{r}, \quad r = \frac{1}{\frac{d^2 y}{d x^2}}.$$

Therefore, $F = \frac{w}{g}\frac{d^2 y}{d x^2} v^2$. If $\frac{d^2 y}{d x^2}$ is obtained from the above equation of the curve, it is seen that this formula is identical with the previous one.

The deflection of the curve at the center of the span is $\frac{1}{3}$ in.

From these results, it is evident that at the high speeds here assumed an apparently trifling deviation from a straight line motion produces a large variation in pressure on the contact conductor.

If a roller weighing 25 lb. is used as a current collector, its pressure on the contact conductor when at rest should be 25 lb., if it is certainly to touch the conductor at the center of each span. The pressure, when it is at the suspenders, is then 25 + 41.2 = 66.2 lb. With the rod assumed, this would produce compression in the suspenders and would also produce larger strains than desirable in the rod. From the formula for $F$, it is clear that doubling the velocity means a four-fold increase in the variation of pressure on the contact rod, due to velocity. In the foregoing it has been assumed that the curve of the contact rod remains unchanged when the collector passes. The collector, when at the center of the span, exerts only a trifling pressure on the rod. This pressure slightly diminishes the deflection and curvature, and improves the contact. When the collector is at or near a suspender it exerts a considerable pressure, but it diminishes the tension in the suspender nearly the same amount; this largely neutralizes its effect on the curvature. The error in the foregoing results, therefore, is small.

The proper size of the contact rod evidently depends on the maximum train speed and on the oscillating weight of the collector. With a speed of 80 miles an hour, and a rigid collector weighing 25 lb. above the supporting springs, a rod $1\frac{1}{4}$ in. in diameter is advisable.

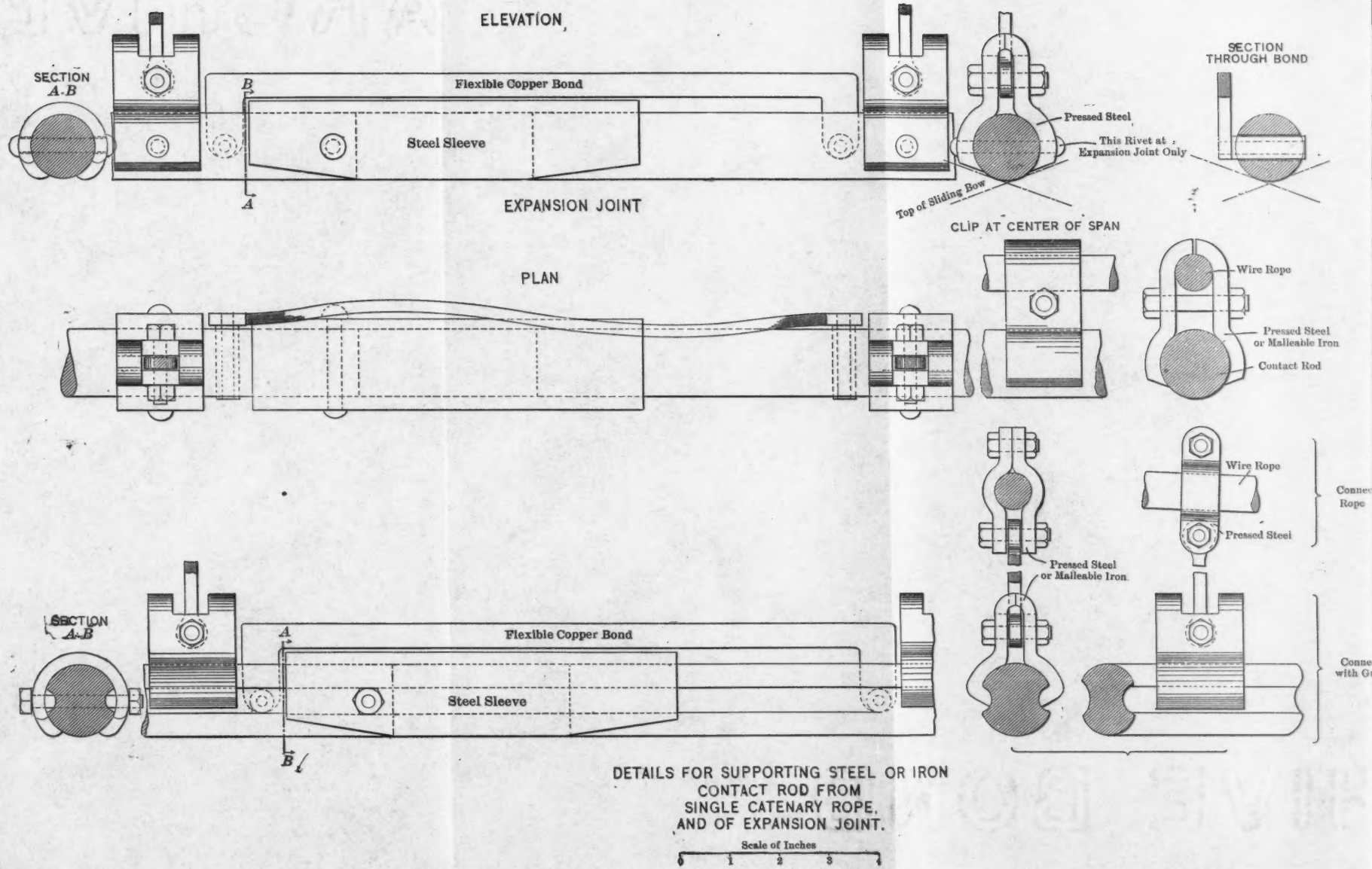
With this rod, the suspenders can be spaced 12 ft. apart without risk of compression when the sliding bow passes. Calculation shows that the center deflection of such a rod is only $\frac{1}{3}$ in. The up and down oscillation of the collector increases the pressure on the contact conductor 22 lb. when it passes the suspender, and it decreases the pressure 11 lb. when it is at the center of the span. The pressure when at rest may be made 20 lb. The maximum pressure will then be 42 lb., and the minimum 9 lb. The largest bending

strain per square inch in the rod will be so small that it will be safe even with welds of mediocre quality. The collector roller might be considerably heavier than 25 lb. without risk of breaking the contact rod. With a 1¼-in. contact rod, therefore, it is easy to design a rolling collector which has abundant strength and is very durable, thus greatly diminishing the cost of maintenance.

A contact rod with an expansion joint and suspender clips is shown in Plate LIX.

### Contact Wire.

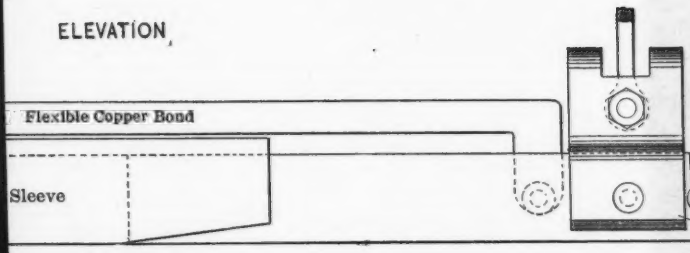
A contact wire under tension, with suspenders 10 ft. apart, is practically straight. When the sliding bow comes along, it is bent up. The deflection varies with the pressure of the sliding bow and the tension in the wire, in short spans, also inversely with its stiffness. With 140° fahr. variation of temperature, the tension is 26 820 lb. per sq. in. more at the minimum than at the maximum temperature. The total strain in the wire from all causes should never reach the elastic limit. The elastic limit of a hard-drawn 0000 copper wire is about 35 000 lb. per sq. in. It has previously been seen that a very small deflection of the contact conductor with very even curves produces a large variation in the pressure between the current collector and the contact conductor. A deflection of ⅛ in. at the center of a 12-ft. span produced a variation of 33 lb. in the pressure of a collector weighing 25 lb. This variation in pressure arises from, and is proportional to, the sum of the maximum acceleration and retardation of the vertical motion of the collector. Assuming 10-ft. spans between two succeeding suspenders of the contact wire, the time of one oscillation of the vertical motion is ten-twelfths of the time with the above considered 1¼-in. contact rod of 12-ft. span. From the general formula for uniform accelerated motion, $s = \frac{g}{2} t^2$, or $g = \frac{2s}{t^2}$, where $s$ is the space covered, $g$ the acceleration, and $t$ the time, it follows that, other things being equal, the acceleration is inversely proportional to the square of the time within which a certain distance is covered. If the uniformity of the acceleration and retardation and the amplitude of the vertical motion are the same, then 10-ft. spans require 1.44 times the maximum acceleration of 12-ft. spans. The maximum acceleration with a given uniformity of motion is also proportional to $s$, or, in this case, the amplitude of the vertical motion. The variation of the contact pressure is proportional to the maximum acceleration multiplied by the oscillating weight. The oscillating weight can be reduced by using a sliding bow which is a spring. Only a part of its weight will then move up and down with the lower face of the wire. It will be assumed that it is practicable to reduce in this




DETAILS FOR SUPPORTING STEEL OR IRON CONTACT ROD FROM SINGLE CATENARY ROPE, AND OF EXPANSION JOINT.

Scale of Inches
0 1 2 3 4

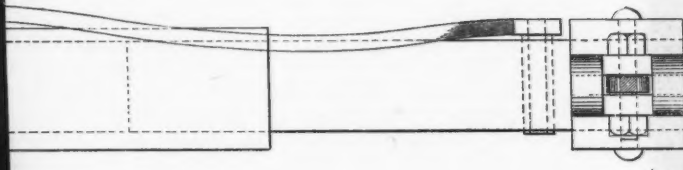
ELEVATION

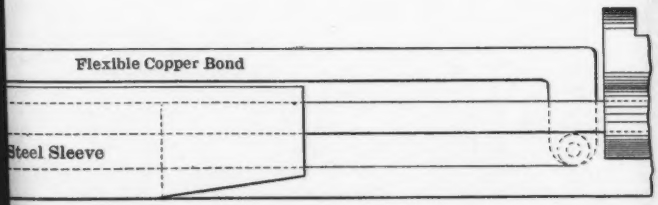



EXPANSION JOINT

Top of Slidi

PLAN



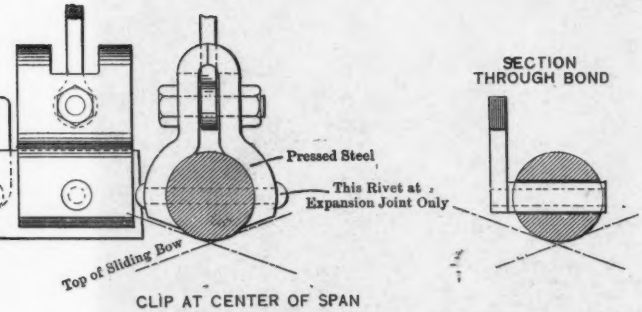



DETAILS FOR SUPPORTING STEEL OR IRON
CONTACT ROD FROM
SINGLE CATENARY ROPE,
AND OF EXPANSION JOINT.

Scale of Inches

0 1 2 3 4

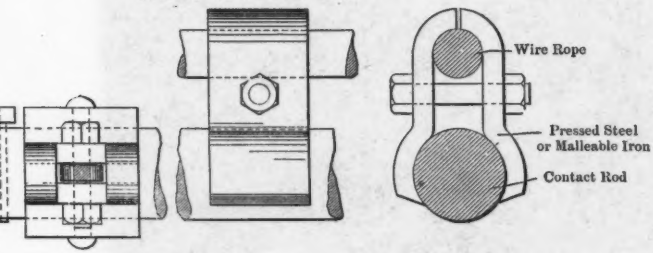
PLATE LIX.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1906.
MAYER ON
STEAM VERSUS ELECTRIC RAILWAY OPERATION.

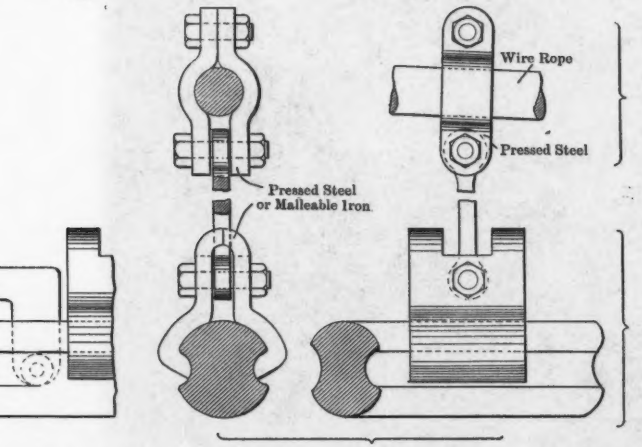



SECTION THROUGH BOND



CLIP AT CENTER OF SPAN




EEL OR IRON
M
PE,
INT.

manner the effective oscillating weight to 6 lb. To obtain a variation of pressure of 33 lb. between the current collector and the contact conductor, the same as with the 1¼-in. rod of 12-ft. span, the amplitude of motion should be $s = \frac{1}{9} \times \frac{25}{6} \times \frac{1}{1.44} = 0.320$ in.

Another course of reasoning for determining the relation between the variation of the contact pressure and the amplitude of the vertical oscillation of the sliding bow is as follows:

The sliding bow presses up with a static pressure, $Z_s$. The contact wire cannot balance this pressure without upward deflection. The sliding bow, therefore, rises between the suspenders and falls at the suspenders. It moves up and down with an accelerated or retarded motion. If the upward acceleration is $\alpha$, if $w$ is the weight of the oscillating part of the sliding bow, if $g$ is the acceleration of gravity, and if $Z_d$ is the varying dynamic pressure of the sliding bow, then $Z_d = Z_s - \alpha \frac{w}{g}$.

The largest positive and the largest negative value attained by $\alpha$ determine, with a given train speed and distance of the suspenders and the oscillating weight, the amount of variation of the contact pressure. For a given amplitude of oscillation, $\alpha$ would be smallest if it were constant during the acceleration and constant during the retardation. The oscillation would then consist of a uniformly accelerated upward motion followed by a uniformly retarded upward motion; these would be followed by a uniformly accelerated and a uniformly retarded downward motion. The upward motion would take half the time of one oscillation, the downward motion the other half.

The accelerated upward motion would be one-half, the retarded upward motion would be the other half, of the total upward motion.

The total variation of pressure would be $2 \alpha \frac{w}{g}$. If the variation of pressure be taken as 33 lb., and $w = 6$ lb., then $\frac{2 \alpha \times 6}{12 \times 32.2} = 33$, and $\alpha = 1\,062.6$ in.

The amplitude of the oscillation would be the distance covered during the accelerated, plus that covered during the retarded, upward motion. The time for each of these is $t = \frac{0.0852}{4} = 0.0213$ sec. The amplitude $A = \alpha t^2 = 0.4824$ in. In reality, the acceleration during the accelerated upward motion varies from a maximum to 0, and the retardation increases from 0 to a maximum. It is evident, therefore, that the amplitude, 0.4824, is much larger than the actual one. The assumption that the acceleration uniformly

decreases from the beginning to the end of the upward motion, being at the end of upward motion negative and equal to the acceleration at the beginning, therefore corresponds more closely to the facts than the assumption above made.

In accordance with this new assumption, $\alpha_{max.} = 1\ 062.6$ in. and $\alpha = 1\ 062.6 - c\ t$, $t = 0.0426$, corresponds to the end of the upward motion. Then, $-1\ 062.6 = 1\ 062.6 - c \times 0.0426$, or $c = 49\ 880$. Therefore, $\alpha = \frac{d^2\ y}{d\ t^2} = 1\ 062.6 - 49\ 880\ t$.

By integrating:

$$\frac{d\ y}{d\ t} = 1\ 062.6\ t - 24\ 940\ t^2 + c,$$

for $t = 0, \frac{d\ y}{d\ t} = 0,$

therefore $c = 0.$

By integrating again:

$$y = 531.3\ t^2 - 8\ 313.3\ t^3 + c,$$

for $t = 0, y = 0,$

therefore $c = 0.$

For $t = 0.0426$, $y = 0.3215$ in. which is the amplitude of oscillation. The value previously found, namely, 0.320 in., is confirmed, therefore, as at least approximately correct.

The minimum tension in the wire which will limit the amplitude of oscillation to 0.320 in. must now be determined. The static pressure of the sliding bow will be assumed to be 20 lb., and the oscillating weight 6 lb. If the sliding bow were not opposed during the upward motion, which is assumed to cover half the time of one oscillation, it would rise a distance, $s = \frac{2032.2}{6 \times 2} \times 12 \times 0.0426^2 = 1.17$ in. The opposing pressure of the wire must reduce this to 0.320 in.

The opposing pressure of the wire is due mainly to its stiffness and its tension.

Assume a 0000, B. & S. gauge, hard-drawn, copper wire of elongated cross-section, equivalent to two 0 wires touching and connected at contact. Such a wire has a depth of cross-section of 0.65 in. and a moment of inertia, around the short axis through the center of the cross-section, of 0.005476 in., and, consequently, a moment of resistance of 0.01685 in. If such a wire with free ends is exposed to a deflecting force, $P_b$, acting at a distance, $c$, from one end and $c_1$ from the other end of a 120-in. span, the equation for its deflections at the point of application, of $P_b$ is $f_b = \frac{P_b}{EI} \frac{c^2 c_1^2}{3l}$

Introducing the foregoing values of $E$, $I$ and $l$, gives

$$f_b = \frac{P_b\, c^2\, c_1{}^2}{39\,427\,200}; \text{ or } P_b = \frac{39\,427\,200}{c^2\, c_1{}^2} f_b.$$

If a flexible wire is exposed to a tension, $T$, and is deflected by a force, $P_t$, acting at the distance, $c$, from one end of the span, as shown in Fig. 1, then, for small deflections, approximately:

$$\left\{\frac{f_t}{c} + \frac{f_t}{c_1}\right\} T = P_t,$$

or

$$\frac{c + c_1}{c\ c_1} f_t\, T = P_t,$$

$$c + c_1 = l,$$

therefore,

$$P_t = \frac{l}{c\, c_1} f_t\, T.$$

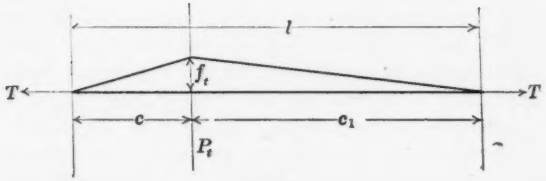



FIG. 1.

The total resistance opposed to deflection by a stiff wire under tension is approximately $P_b + P_t$. Table 1 gives, for different values of $c$ and for a deflection of 0.1 in., the values of $P_b + P_t$ calculated by the foregoing formulas for a tension, $T = 1\,000$ lb.

TABLE 1.

| | | | | |
|---|---|---|---|---|
| $c = 0.1\ l$; | $P_b + P_t$ | $= 2.348 + 9.260$ | $= 11.608$ | lb. |
| $c = 0.2\ l$; | $P_b + P_t$ | $= 0.743 + 5.208$ | $= 5.951$ | " |
| $c = 0.25\ l$; | $P_b + P_t$ | $= 0.541 + 4.444$ | $= 4.985$ | " |
| $c = 0.30\ l$; | $P_b + P_t$ | $= 0.431 + 3.968$ | $= 4.399$ | " |
| $c = 0.40\ l$; | $P_b + P_t$ | $= 0.330 + 3.472$ | $= 3.802$ | " |
| $c = 0.50\ l$; | $P_b + P_t$ | $= 0.304 + 3.333$ | $= 3.637$ | " |

Assuming the uniform motion most favorable to a small variation of the contact pressure, then the minimum pressure is 16.5 lb. less than the static pressure of 20 lb., or equal to 3.5 lb. The upward motion occurs approximately at the center half of the span; its beginning is about when $c = 0.25\ l$. The deflection of the wire is then $0.1 \times \frac{3.5}{4.985} = 0.07$ in. If the amplitude of oscillation is 0.320 in., the deflection at the end of the upward motion is 0.39 in. With this deflection, and with $c = 0.75\ l$

(which gives the same pressure as $c = 0.25\ l$) the opposing pressure is $4.985 \times 3.9 = 19.44$ lb. The opposing pressure should be $33 + 3.5 = 36.5$ lb. With the tension assumed, the amplitude of the oscillation would be larger. It would be about 0.67 in. if the variation of pressure did not increase with the larger amplitude. This result indicates that the tension assumed is not adequate to prevent the jumping of the sliding bow. The upward motion, however, may take place not quite at the center half of the span. If it begins with $c = 0.3\ l$ and ends with $c = 0.8\ l$ the deflection of the wire at the beginning is $0.1 \times \frac{3.5}{4.4} = 0.08$. $0.320 + 0.08 = 0.4$, and the opposing pressure at the end is $4 \times 5.951 = 23.804$. This opposing pressure is also quite inadequate.

If the upward motion did occur between $c = 0.4$ and $c = 0.9$, then the opposing pressure at the end of the upward motion would be ample. It is evident, however, that the upward motion will occur near the middle half of the span, where the resistance opposing it is smallest. The writer believes that the above reasons amply justify the statement that a tension in the wire of less than 1 000 lb. is certainly inadequate to prevent the jumping of the sliding bow.

Increasing the static pressure of the bow is no remedy for the evil, as this would increase the deflections or the amplitude of the vertical oscillation, consequently the maximum acceleration and retardation and the variation of the contact pressure. The only remedies are a diminution of the oscillating weight or an increase of the tension in the wire. The various small inaccuracies in the foregoing calculation are not great enough to vitiate the above inference because the deficiency in the opposing pressure of the wire is very large. The writer has assumed that it is practicable, by a spring support of the wire at the suspender, to regulate the vertical oscillation of the sliding bow so that the up and down motions each take one-half the time of one oscillation. If the oscillation is irregular, which is probably unavoidable, then the maximum acceleration and retardation during the more rapid part of the oscillation will be larger than estimated above, the variation of contact pressure will be greater, and a greater tension in the wire will be required to prevent jumping and consequent sparking. The above minimum tension of 1 000 lb. is 6 000 lb. per sq. in. of wire. The maximum tension per square inch at the lowest temperature is $6\,000 + 26\,820 = 32\,820$ lb. This will be increased by the normal pressure of the passing sliding bow.

The writer will now consider the effect of the pressure of the sliding bow on a wire under great tension. The wire will be bent up. If $T$ is the tension and $P$ is the deflecting force, then the wire, near $P$, will be bent in a curve.

If the angle of the two end tangents is $\alpha$ then $\alpha = \frac{P}{T}$ for small values of $P$. The bending moment at any point, $A$, is equal to $T \times Aa$, or $T$ multiplied by the distance of the end tangent from the point, $A$, of the curve. At the point of application of $P$, the bending moment is largest, and is equal to $c\,D \times T$. If the height of the cross-section of wire is $h$, and if $r$ is the radius of curvature of the wire at any point, then the bending strain per square inch in the extreme fiber is $s = \frac{h}{2\,r}$ 20 000 000 lb., where 20 000 000 lb. is the modulus of elasticity of copper wire. $h = 0.65$ in.

Therefore,

$$s = \frac{6\ 500\ 000 \text{ lb.}}{r}$$

Also, $s = \frac{M}{R}$, where $M$ is the bending moment of the external forces and $R$ is the moment of resistance of the cross-section of the wire. From these equations, $r = \frac{6\ 500\ 000}{M} R$.

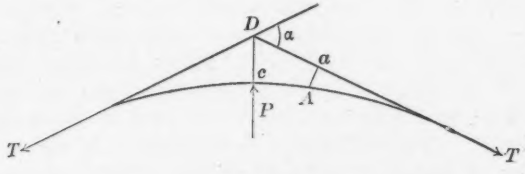



FIG. 2.

The value of $c\,D$ corresponding to a given value of $\alpha$ would be smallest if the maximum curvature extended over the whole length of the curve or if the curve were a circle. In this case, $c\,D$ would be equal to $\frac{r\,\alpha^2}{8}$, and the bending moment at the contact point of the sliding bow would be $M = \frac{r\,\alpha^2}{8} T$, or, introducing for $\alpha$ its value, $\frac{P}{T}$, then $M = \frac{r\,P^2}{8\,T}$. Introducing the above value of $r$, gives $M = \frac{812\ 500\ P^2}{M\,T} R$, or $M = P\sqrt{\frac{812\ 500\ R}{T}}$, and $s = \frac{M}{R} = \frac{P \times 901.4}{\sqrt{R\,T}}$.

The maximum value of $T = 32\ 820$ lb. per sq. in., or $T = 5\ 470$ lb. $R = 0.01685$ in. $P$ is the maximum pressure of the sliding bow. This will be assumed to be 24 lb. Then, to obtain $s$:

$$s = \frac{24 \times 901.4}{\sqrt{5\ 470 \times 0.01685}} = 2\ 253 \text{ lb.}$$

This value of $s$ is not the actual value, but the value corresponding to a circular curve. The curve actually straightens out toward the ends. The length of the curve corresponding to the angle, $\alpha$, and the distance, $c\ D$, therefore, is greater than assumed. From this it is known that the bending strain in the wire, per square inch of extreme fiber, is considerably more than 2 253 lb.

When there is a wind, the wire is blown to leeward, and the long axis of the cross-section becomes inclined instead of vertical. The upward pressure of the sliding bow will twist the wire when the contact point is near the center of the span so that the long axis becomes still more inclined. If it were horizontal, the bending strain would be 1.58 times as large as above calculated.

The bending strain must be added to 32 820 lb. to obtain the total strain. The sum exceeds the elastic limit of the wire.

In view of the fact that breaks of trolley wires of much smaller size seldom occur, it is important to bear in mind that the variation of the pressure of the current collector, and consequently its maximum pressure, varies approximately as the square of the frequency of oscillation. The frequency of oscillation varies as the train speed, and inversely with the span. The deflection caused by the sliding bow varies approximately as the span and as the pressure of the bow. Short spans between the suspenders of the contact conductor and especially high train speeds are very unfavorable. Any favorable inference drawn from the experience on trolley lines, therefore, is not well founded, since the conditions are demonstrably vastly different. Rope suspension is responsible for an increase in the variation of tension of the contact wire due to changes of temperature. This variation is the most important cause of trouble. The high voltage used demands absolute safety; the safety secured by an ordinary trolley line, therefore, is inadequate and should be improved.

## Summary.

The result of this investigation may be summed up as follows:

A 1½-in. contact rod suspended from one rope hung in 300-ft. spans, by suspenders 12 ft. apart, sags only $\frac{1}{9}$ in. at the center of each 12-ft. span. The current collector, if moving with a speed of 80 miles an hour, will oscillate up and down about $\frac{1}{9}$ in. while passing under a 12-ft. span. This oscillation produces with an oscillating weight of 25 lb. a variation of contact pressure of 33 lb., which the rod is amply able to resist. The suspenders are never in compression, and the contact rod need not be supported on springs; a simple hinged connection answers every purpose; and a thin tension rod with eyes, or even a wire, may be used for a suspender. The current collector may be a heavy, strong

and durable roller such as has been shown to be satisfactory by past experience.

A contact wire suspendeded from ropes with 300-ft. spans requires two ropes in inclined planes to prevent excessive lateral motion caused by the wind. The suspenders must be stiff triangular frames. The contact wire must be connected to the suspenders by springs arranged so that they will always operate properly. The wire must be under tension to enable it to resist the pressure of the sliding bow. This tension will vary greatly with changes of temperature. The variation in the temperature of a wire exposed to the sun and carrying a variable and considerable current is, in the Northern United States, 140° fahr., or more. It is not possible to adjust the wire so that it will be satisfactory at both extremes of temperature. It will either stretch and occasionally break at the lowest temperature or be so slack in summer that the collector will jump and cause sparking and excessive strains. If the springs which are necessary at the suspenders do not operate properly, or as intended, the oscillating motion of the collector will be jerky and will cause alternately excessive and defective contact pressure, endangering the wire and causing sparking. The breaking of the wire may be accompanied by the rise of the sliding bow above it, and the destruction of a number of suspenders, causing the fall of the wire and possibly fatal disaster. The currrent collector cannot be a substantial roller; it must be an elastic sliding bow, so as to reduce the oscillating weight to the smallest possible amount. It will be difficult to design a tolerably satisfactory sliding bow, and it will cause at best a large cost of maintenance. The only advantage of the wire is its larger conductivity for alternate currents and the consequent saving in the cost of feeders. In short, a contact wire and its accessories make a complicated, short-lived, and unsafe structure, expensive to maintain, while a contact rod is simple, safe and durable.

The writer has applied for a patent on the contact rod shown.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## THE ATCHAFALAYA RIVER: SOME OF ITS PECULIAR PHYSICAL CHARACTERISTICS.

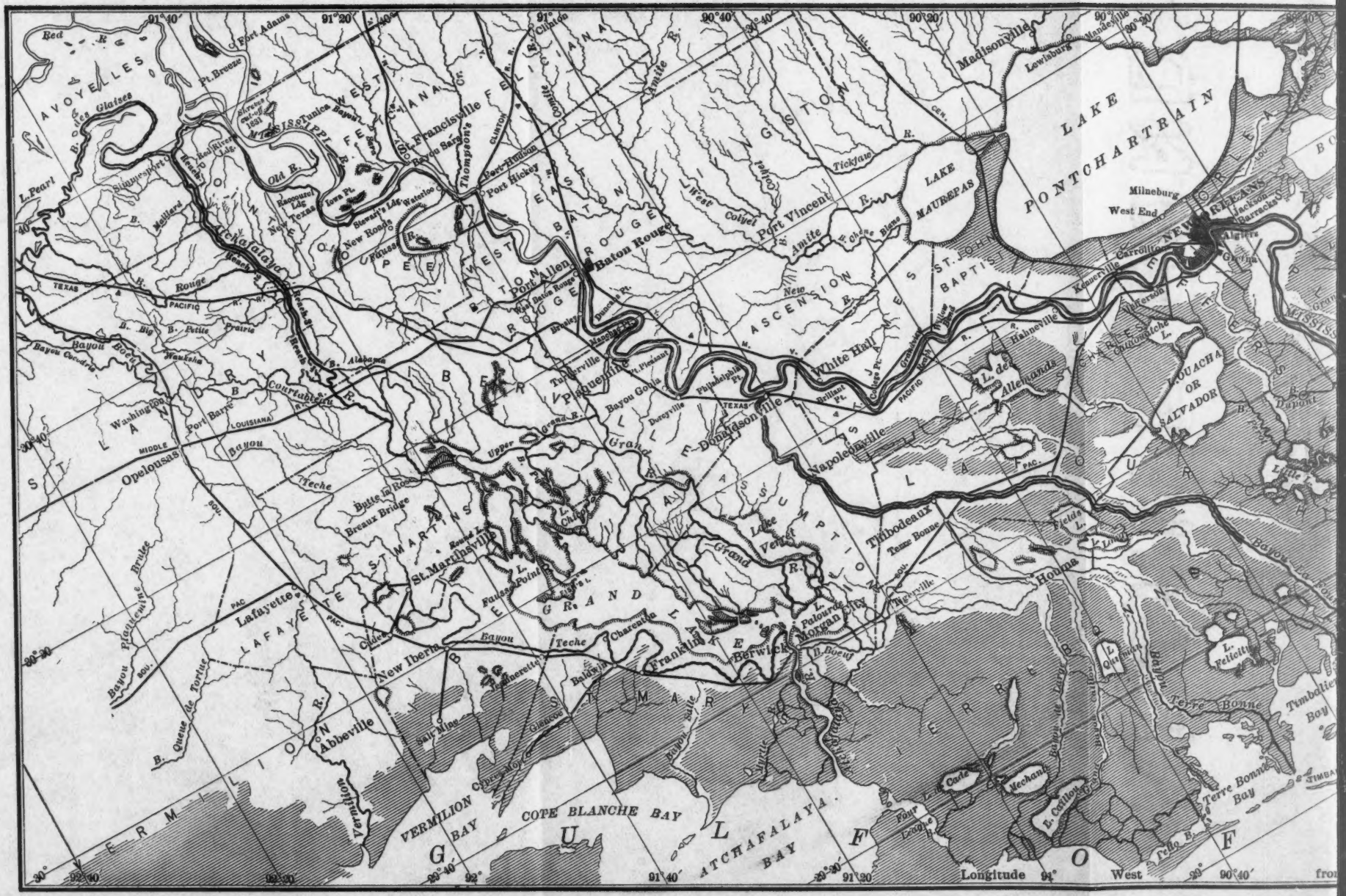
By J. A. Ockerson, M. Am. Soc. C. E.

To be Presented December 5th, 1906.

As the Atchafalaya River, in Louisiana, differs in so many respects from the usual conception of streams, the writer believes that a general description of it will be of more than ordinary interest to the hydraulic engineer, as well as to the layman. It is a stream which is largest at its source and is deepest in places of excessive width.

It is an alluvial stream flowing between banks of its own formation, and having its source at an old bend of the Mississippi River at about latitude 31 degrees. At the present time it is an important outlet of the Mississippi. Opinions differ as to its origin. It is probable that, at one time, it was the bed of the Red River which flowed directly to the Gulf of Mexico, but which was made a tributary of the Mississippi River by the elongation of the bend of the latter which cut into the smaller stream and made the mouth of the Red River near where it is now located. Even be-

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.


LAKE PONTCHARTRAIN
LAKE MAUREPAS
NEW ORLEANS
Jackson Barracks
Milneburg
West End
Carrollton
Algiers
Gretna
Madisonville
Lewisburg
Vandevile
Port Adams
Pt. Breeze
Red R.
Les Glaises
Old R.
Raccourci Lake
Iowa Pt.
Stewart's Lake
Waterloo
New Roads
Fausse R.
Port Hickey
Port Hudson
Thompson's Creek
Clinton
Bayou Sara
St. Francisville
Tunica Bayou
Mississippi R.
Pt. Coupee
Lake Long
Tickfaw R.
Amite R.
West Colyel
Colyel
Port Vincent
Bayou Chene Blanc
Amite R.
Baton Rouge
Port Allen
New Roads
Bayou Sorrel
Bayou Plaquemine
Plaquemine
Pt. Pleasant
Bayou Gotta
Donaldsonville
Napoleonville
Thibodeaux
Houma
Terre Bonne Bay
Timbalier Bay
Lake Verret
Grand R.
Lake Chicot
Round Lake
St. Martinsville
Breaux Bridge
Butte La Rose
Opelousas
Washington
Port Barre
Courtableau R.
Bayou Teche
Upper Grand R.
Grand R.
Lafayette
New Iberia
Franklin
Berwick
Morgan City
Palourde
Abbeville
Vermilion R.
Bayou Queue de Tortue
Bayou Plaquemine Brule
Salt Mine
Glasscock
Baldwin
Charenton
Bayou Teche
Bayou Sale
Lake Palourde
Lake Chicot
Lake Quitman
Lake Felicity
Lake Caillou
Lake Mechant
Four League Bay
Caillou Bay
Bayou Terre Bonne
Bayou Black
Bayou Lafourche
Bayou Boeuf
Bayou Courtableau
Bayou Des Allemands
Lake des Allemands
Lake Salvador
Bayou Salvador
Bayou Dupont
Bayou Gauche
Bayou Lafourche
Bayou Terre Bonne
Bayou Black
Bayou Teche
Bayou Courtableau
Bayou Boeuf
Bayou Plaquemine Brule
Bayou Queue de Tortue
Bayou Sale


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Jackson Barracks
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Amite R.
New R.
White Hall
Donaldsonville
Napoleonville
Thibodeaux
Terre Bonne
Houma
Lake Verret
Grand R.
Morgan City
Berwick
Atchafalaya Bay
Four League B.
Caillou B.
Terre Bonne Bay
Timbalier Bay
Timbalier I.
Timbalier Pass
Bayou Lafourche
Bayou Terrebonne
Bayou Black
Bayou Teche
Bayou Boeuf
Bayou La Fourche
Bayou Des Allemands
Bayou Chacahoula
Bayou Petit Caillou
Bayou Du Large
Bayou Du Pont
Bayou Grand Caillou
Bayou Pelton
Bayou Blue
Bayou Cut Off
Bayou Folse
Bayou Des Ecores

PLATE LX.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1906.
OCKERSON ON
ATCHAFALAYA RIVER.



fore this occurred the Atchafalaya portion served as an outlet for some of the overflow waters of the Mississippi River.

At the head of the Atchafalaya, the entire volume of water is derived from the Mississippi and Red Rivers. Below the source, the drainage from the westward finds its way into the stream through numerous bayous which contribute a considerable amount to its volume. A very large percentage of the flow, however, is contributed by the two streams first named, which in a sense are, therefore, tributaries of the Atchafalaya.

A maximum flood in the Mississippi River delivers to the Atchafalaya River more than 400 000 cu. ft. per sec. At low water little or nothing is derived from this source, and, in fact, the flow is often reversed, a portion of the waters of the Red River passing by the head of the Atchafalaya and flowing into the Mississippi. The low-water discharge of the Atchafalaya is sometimes less than 1 000 cu. ft. per sec., while, at high water, it serves as an outlet for about one-fourth of the flood volume of the Mississippi.

Measured along the channel of the Mississippi, the distance to the head of the Atchafalaya from the Gulf of Mexico is some 315 miles. Following down the latter stream, it is found that it reaches the Gulf in a distance of about 156 miles, at a point 125 miles west of the mouth of the Mississippi. It practically reaches tide water at Grand Lake, a distance of only about 100 miles from its source. (See Plate LX.)

At the head of the stream the banks are 50 ft. above mean Gulf level, or 48 ft. above extreme low water, and rapidly decrease in height as one goes down stream. At Butte la Rose, 67 miles from the source, the banks are only 12 ft. above the same datum, giving a difference of 38 ft., or a ground slope of 0.57 ft. per mile.

The water surface slope for the same reach, at a stage near bank-full at the lower end, is 14.6 ft., or an average water slope at that stage of 0.22 ft. per mile.

The excess in the height of the banks near the source is readily accounted for by the fact that they are built up by the sediment carried in the water, which not only rises much higher at the upper end, but a greater proportion of the sediment is dropped in its first escape from the banks of the streams which are always submerged at high water.

At the source of the stream there is a maximum oscillation of stage, between high and low water, of 52.3 ft. A mile below the source, the stream is 900 ft. wide between the tops of the banks, with a maximum depth of 85 ft. at bank-full stage. At Butte la Rose the width is 350 ft., with a maximum depth of 58 ft. At the head of Alabama Bayou, which depletes the stream to some extent, the width is 650 ft., and the maximum depth 65 ft. The depletion by Alabama Bayou is very largely recovered by the return flow of the same bayou, and by the inflow of several bayous from the westward.

When the Mississippi River flowed bodily around the bend, past the mouth of the Red River (Fig. 1) and the head of the Atchafalaya, vast accumulations of drift were carried down the latter stream, which finally choked it up, forming a compact mass of floating trees and logs known as "raft."

This raft began about 20 miles below the source and continued with intervals of open water for about 20 miles down stream. It was so dense in places, that, although rising and falling with the variations of stage, willow trees grew upon it, and in some places it served the purpose of a bridge which was readily crossed by cattle. "Shreves Cut-off" was made in 1831 (Fig. 2), and the main body of the Mississippi, with its burden of drift, no longer flowed by the head of the Atchafalaya, and the growth of the raft practically ceased.

The banks of the Atchafalaya, down to Butte la Rose, were occupied by flourishing settlements, and the demands of navigation called for the removal of the raft so as to permit the passage of water craft laden with the products of the fertile soil. The work was begun by the State of Louisiana prior to 1860, and continued for several years until a channel was finally opened through it. The immediate result of the removal of these obstructions was a great increase in the velocity and a consequent tendency toward enlargement, through the erosion of both bed and banks. It also increased the volume of the floods, and levees to protect the lands from overflow became necessary. The levee on the right bank extends down stream a distance of about 37 miles from its source. This levee begins at high ground some miles up the Bayou de Glaise.

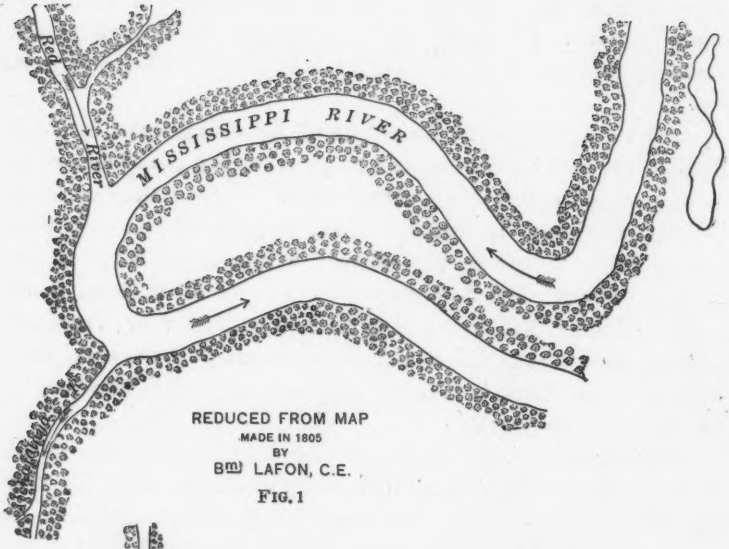

Red River
MISSISSIPPI RIVER
REDUCED FROM MAP
MADE IN 1805
BY
Bm LAFON, C.E.

FIG. 1

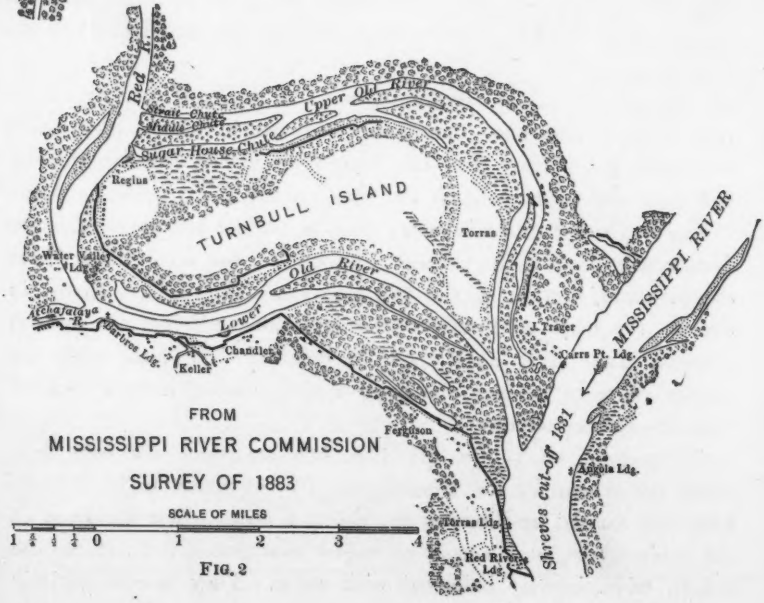

Red R.
Upper Old River
Sugar House Chute
TURNBULL ISLAND
Regina
Torras
Old River
Lower
Atchafalaya R.
Keller
Chandler
Ferguson
Shreves cut-off 1831
MISSISSIPPI RIVER
Carrs Pt. Ldg.
Angola Ldg.
Torras Ldg.
Red River Ldg.
FROM
MISSISSIPPI RIVER COMMISSION
SURVEY OF 1883
SCALE OF MILES
1 0 1 2 3 4

FIG. 2

The levee on the left bank connects with the Mississippi River levee system, and continues along the Atchafalaya a distance of some 43 miles. Below the ends of the levee the flood waters are scattered through the bayous, swamps and lakes on their way to the sea.

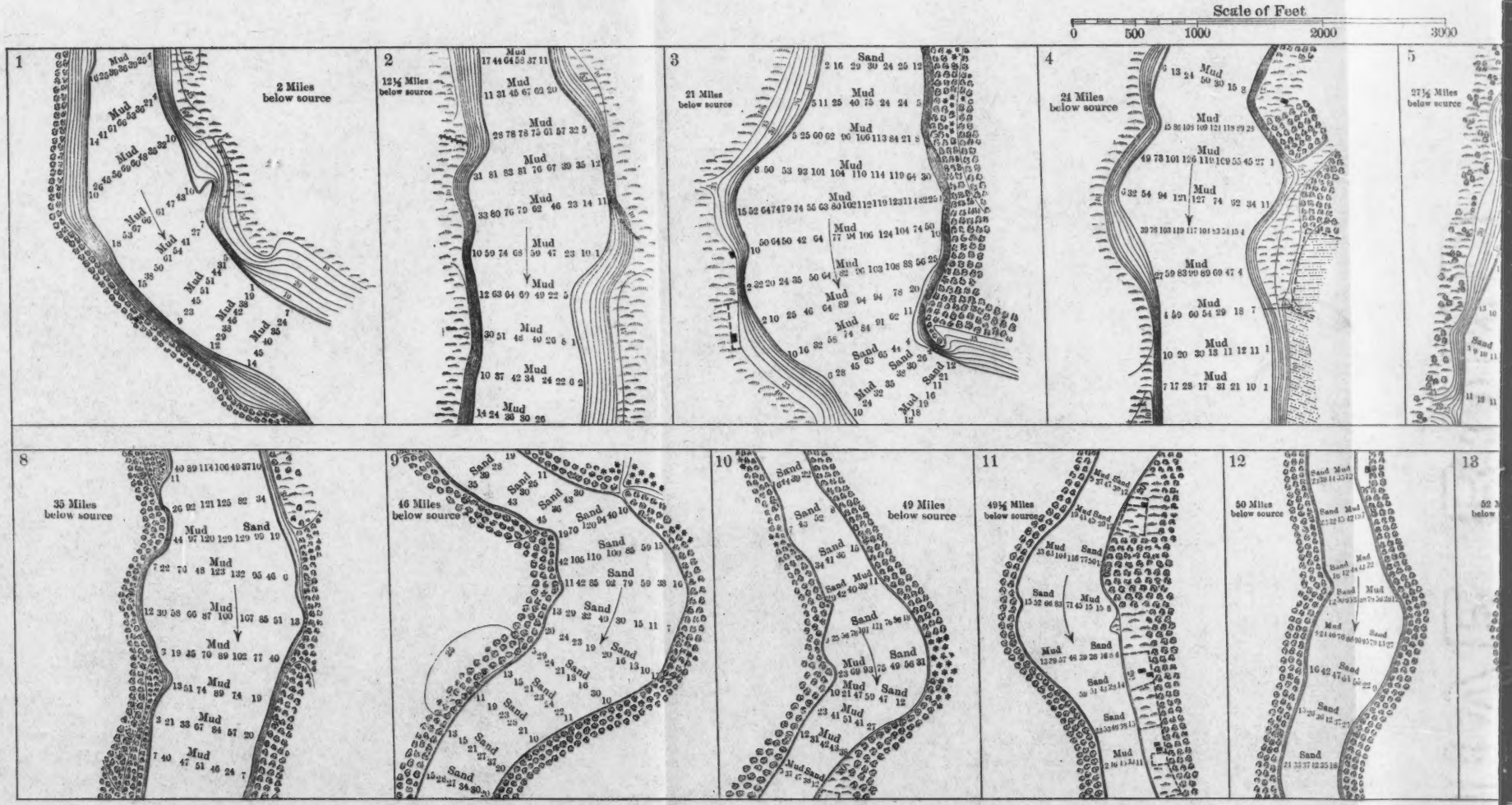
Definite figures as to the extent of the enlargement, from the days of the raft to 1880, cannot be given, owing to the lack of accurate surveys covering the early period. If the testimony of the "oldest inhabitant" is accepted as correct, the stream, at a point 5 miles below its source, has enlarged within the memory of man from one which could be crossed on a foot-log 40 ft. long, to the present stream 650 ft. wide and 40 ft. deep at low water. There are, however, good reasons for doubting the accuracy of the early testimony as to the width, but, at the same time, a great enlargement of the channel is apparent.

The masses of drift still found embedded in the banks of the stream suggest that at some remote time the channel was even larger than it is now. The enormous quantity of raft also indicates a very great outflow of water which brought the material down the waterway.

On account of the shorter distance to the Gulf by way of the Atchafalaya, and the consequent increase in slope, there have long been grave fears that the main river would abandon its own bed and take this route to the sea, leaving New Orleans, Baton Rouge and other cities inland. Such a radical change would also disastrously disturb the regimen of the river for many miles above the present junction of the two streams. The Yellow River, in China, furnishes a forcible precedent for anticipating such a change. This river abandoned its original bed and took the shorter route to the sea, the present mouth being some 200 miles from the former mouth.

To prevent such a catastrophe, two mattress sills were laid across the stream by the Mississippi River Commission in 1887-89. They are located at Simmesport, about 4 miles below the head of the Atchafalaya, and consist of willow mattresses, 3 ft. thick and 300 ft. wide, heavily ballasted with stone. They extend entirely across the stream and up to the high-water banks. The two sills

# SHORT REACHES OF THE ATCHAFALAYA RIVE
## SHOWING MARKED VARIATIONS IN DEPTH AND WIDTH, THE GREATEST DEPTH BEING COINCIDENT



# SHORT REACHES OF THE ATCHAFALAYA RIVER.

## S IN DEPTH AND WIDTH, THE GREATEST DEPTH BEING COINCIDENT WITH THE GREATE

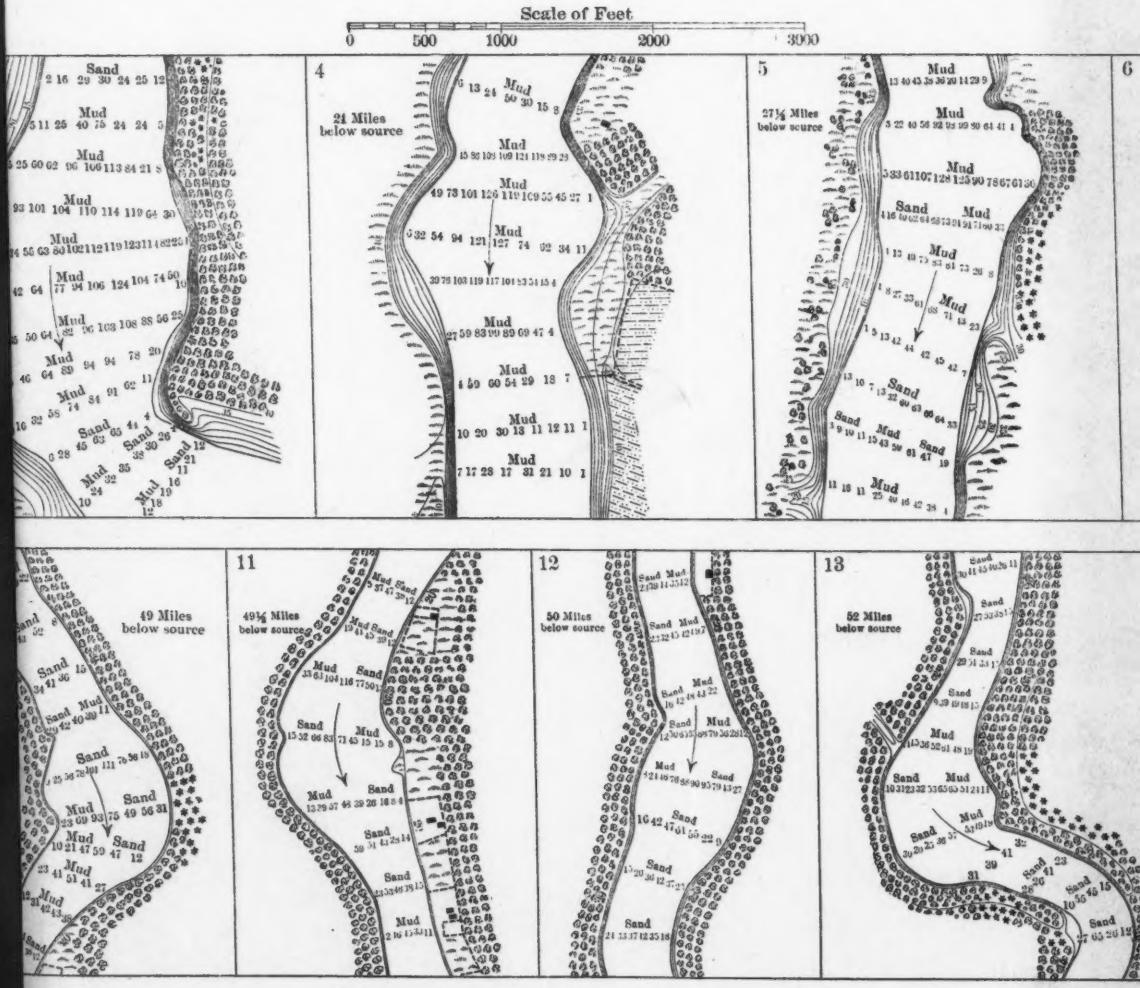
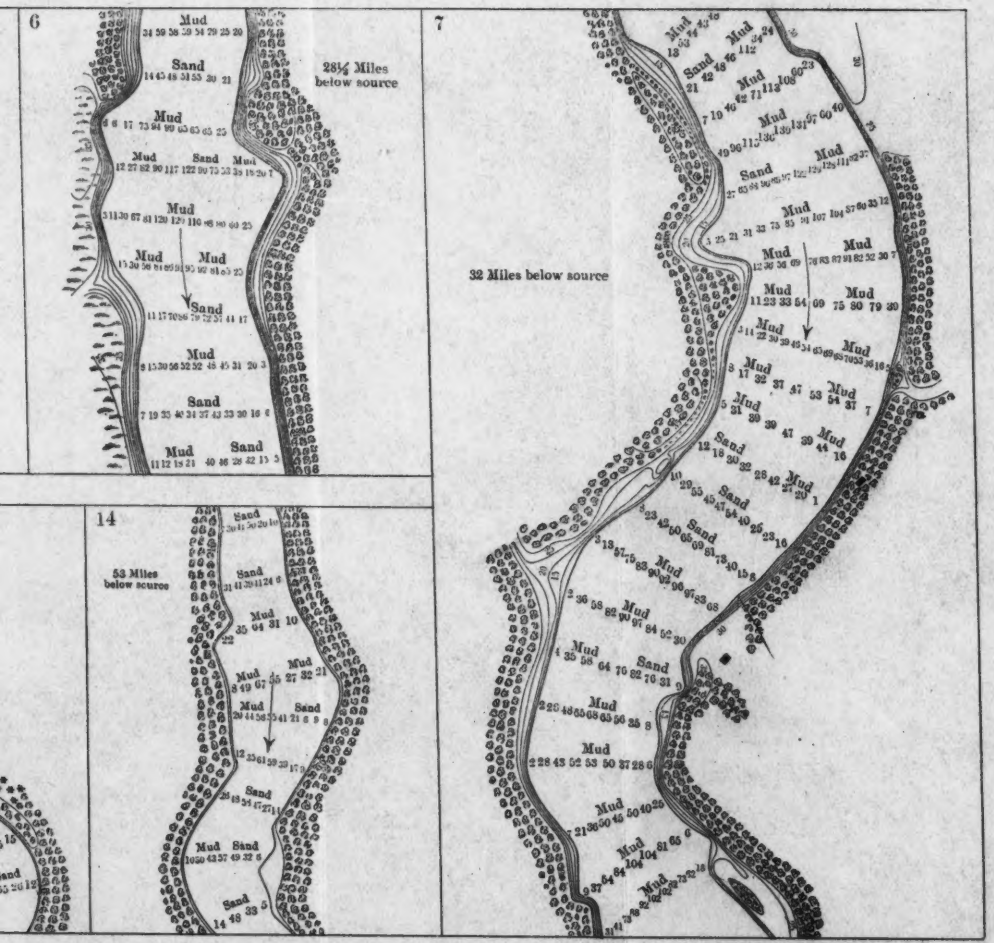


PLATE LXI.
PAPERS, AM. SOC. C. E
SEPTEMBER, 1906.
OCKERSON ON
ATCHAFALAYA RIVER.

ATEST WIDTH. SURVEY OF 1905.





are about 1 800 ft. apart, and have effectually prevented further enlargement of the section of the river at this point.

In the meantime a decided tendency toward the closure of the lower old river, near the present position of the Mississippi, by deposits of sediment, threatened to divorce both the Red and Atchafalaya Rivers from the main river (Figs. 1 and 2). This was a serious menace to the navigation interests of these streams, and, in order to meet the requirements of these interests, it became necessary to resort to dredging during each low-water season. The channel is still maintained in this way.

On the completion of the locks at Plaquemine, on the Mississippi River, now under construction, access to the two streams above named will be by the Bayou Plaquemine and the Upper Grand River, as well as by the present route.

The deposits from the sediment-laden waters of the Mississippi are gradually building a barrier of great proportions between its banks and the head of the Atchafalaya, which will have the effect of depleting more and more the volume contributed by the Mississippi during floods. Were the dredging suspended, this depletion would doubtless be greater from year to year, and, as it goes on, it necessarily means an increase in the flood volume of the main stream below the juncture and a decrease in the volume of the Atchafalaya, the greatest load of which would finally be the Red River floods.

Whether the banks and bed of the Mississippi River will accommodate themselves to the increased volume without undue strain, as the barrier develops, is an important question, which has received a great deal of careful study, and is still under consideration.

A survey of the Atchafalaya, made about a year ago by the Mississippi River Commission, brings to light some of the peculiarities of the stream, and also furnishes data from which can be determined the changes that have occurred during the 25 years which have elapsed since the previous survey was made.

The doctrine of contraction as a means of increasing the depth of streams is almost universally accepted as correct. In this stream there are repeated and radical violations of this principle under natural conditions, as a glance at Figs. 1 to 14, Plate LXI, will

show. The extremes, in contiguous narrow and wide stretches, are shown in Table 1.

TABLE 1.—WIDTHS AND DEPTHS ON CONTIGUOUS WIDE AND NARROW SECTIONS OF THE ATCHAFALAYA RIVER.

| Section. | Distance from source, in miles. | NARROW SECTION. | | WIDE SECTION. | |
|---|---|---|---|---|---|
| | | Width, in feet. | Depth, in feet. | Width, in feet. | Depth, in feet. |
| 1 | 2 | 500 | 39 | 825 | 69 |
| 2 | 12½ | 575 | 64 | 1 100 | 83 |
| 3 | 21 | 800 | 30 | 1 620 | 124 |
| 4 | 24 | 750 | 34 | 1 300 | 127 |
| 5 | 27½ | 700 | 49 | 1 075 | 128 |
| 6 | 28½ | 650 | 55 | 1 150 | 122 |
| 7 | 32 | 750 | 48 | 1 200 | 139 |
| 8 | 35 | 700 | 54 | 1 200 | 132 |
| 9 | 46 | 500 | 39 | 1 050 | 120 |
| 10 | 49 | 350 | 41 | 800 | 114 |
| 11 | 49½ | 400 | 45 | 800 | 116 |
| 12 | 50 | 450 | 45 | 720 | 95 |
| 13 | 52 | 300 | 49 | 730 | 65 |
| 14 | 53 | 470 | 41 | 720 | 67 |

In the case of Section 3, where the width is more than double that of the narrow section, the depth is more than four times as great. All the cases cited are striking, in this respect.

Plate LXI shows fourteen reaches of the river as derived from the survey of 1905. The figures in the stream indicate the depths in feet below the stage when sounded. This stage did not in any case reach the top of the banks, but ranged from low to medium stage. The contour intervals along the banks are 5 ft., and the figures indicate the elevations of the banks above mean Gulf level. The character of the bottom, as revealed by the sounding lead, is noted at frequent intervals.

Plate LXI amplifies the results in Table 1, and shows graphically, in a very forcible manner, that in this river a narrow channel means less depth, and that excessive width is invariably accompanied by great increase in depth.

No satisfactory explanation of the cause of these great holes has been found. It has been suggested, since they occur mainly in the reach formerly occupied by the "raft," that the washing out of the drift accounts for the holes; but, where the bed and banks have been rip-rapped with logs and trees embedded in the soil, it would seem to be more difficult to erode them than where no such obstruc-



FIG. 1.—HEAD OF ATCHAFALAYA RIVER, NOVEMBER 16TH, 1900.



FIG. 2.—ON THE ATCHAFALAYA RIVER, NOVEMBER 17TH, 1900.



FIG. 3.—HEAD OF BAYOU ALABAMA, NOVEMBER 26TH, 1905.

tions existed. Furthermore, a given volume of water flowing along a stream of uniform slope should have the greatest velocity in the smallest section, neglecting the item of friction. Double the area of the section, and the velocity required to carry the volume should be reduced one-half and its eroding power be correspondingly reduced.

Another suggestion is that levee building along the river has progressed by stages, and that the flood waters have been confined until they reached the ends of the levee, where they were set free with an enormous increase in slope at that point, and consequently with greatly increased velocity, which expended itself in whirls and eddies which attacked both bottom and sides of the stream. In that case the succession of holes should coincide with the successive prolongations of the levee system. The holes are limited in length, and are adjacent to much narrower and shallower sections which must also have been within the sphere of influence of the exaggerated slope, if such slope actually existed.

The closing of outlet bayous, which, when open, carried off considerable of the volume, doubtless had much to do with the enlargement of section in the lower reaches.

In streams like the Mississippi and Missouri, the maximum erosion is invariably in the bends or concave shores, which continue to elongate until a cut-off occurs, and the length is restored to normal conditions. In the Atchafalaya, however, the erosion has been largely confined to the points, or convex shores, the direct effect being a material reduction in its length.

It is evident, from the conditions already described, that in case an increase in the navigable depth of the shallow reaches were required, the engineer would probably find it necessary to abandon the usual practice of contraction in such cases, and resort to other means to secure the desired results.

The survey recently made provides the data necessary for a study of the changes, and throws considerable light on the causes thereof. This study has consisted mainly of a comparison of the area, depth and width of some 278 cross-sections, at low, medium, and bank-full stages, which are practically common to the surveys of 1880-81 and 1904-05. In order to deduce mean elements for certain lengths of the stream, it was first divided arbitrarily into

reaches 5 miles in length. This, while indicating certain tendencies, failed to satisfy all the requirements, and a division into reaches conforming to the several epochs of levee building was finally resorted to as the most rational. A division of the river on this basis gives four well-defined reaches, and the comparison of the mean elements of the two surveys on this basis leads to certain conclusions which afford satisfactory explanation of some of the phenomena observed.

The mean results are set forth in Table 2.

The location of the reaches is shown on Plate LX. Reach 1 begins at the head of the river and extends down stream 13.7 miles. The levees covered both banks at the time of the first survey, and the flood control, therefore, was more or less complete during the entire interval between the two surveys; the only change in the conditions was the enlargement and strengthening of the levees, which added chiefly to their safety, rather than to their utility in the matter of flood control. It will be seen that in this reach the depths and area of the mean low-water section have decreased, and the enlargement of the high-water section has been due to a very moderate erosion of the banks. In short, the bed of the stream had long since adapted itself to the volume which it was required to carry, and practically stable conditions were the result.

In Reach 2, which covers the next stretch of 16.1 miles, there was a levee on the left bank for its entire length at the time of the first survey. This levee was more or less effective during the interval elapsing between the two surveys, but there was no levee on the right bank. The right bank levee was first effective for flood control some 12 years after the first survey was made, and this for about half the length of the reach. The lower half was not effective until some 4 years later. In this reach it is found that when the first survey was made, there was already considerable enlargement due to the influence of one levee for the entire length, and the enlargement continued when the flood control was completed by the construction of the right bank levee. There are also indications here, showing that the very deep pools have filled up in the upper portion where the levee conditions have been practically the same during several floods.

Reach 3 covers a distance of 7.1 miles. At the time of the first

TABLE 2.—MEANS OF CROSS-SECTION ELEMENTS BY REACHES, AND CHANGES DEVELOPED IN THE INTERVAL BETWEEN THE SURVEYS OF 1880–81 AND 1904–05.

| Reach. | Stage. | Widths, in Feet. | | Changes. | | Areas, in Square Feet. | | Changes. | | Mean Depths, in Feet. | | Changes, in Feet. | Maximum Depth, in Feet. | | Changes, in Feet. | Bank Elevations, in Feet. | | Changes, in Feet. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1880–81. | 1904–05. | Feet. | Per Cent. | 1880–81. | 1904–05. | Square Feet. | Per Cent. | 1880–81. | 1904–05. | | 1880–81. | 1904–05. | | 1880–81. | 1904–05. | |
| 1. 13.7 miles. | Low water. | 639 | 712 | + 73 | +11.4 | 17 902 | 15 697 | − 2 205 | −12.3 | 27.1 | 22.1 | −5.0 | 48.3 | 94.5 | − 8.8 | 46.4 | 47.4 | +1.0 |
| | Bank-full. | 994 | 1 147 | +153 | +15.4 | 53 171 | 55 572 | + 2 401 | + 4.5 | 53.4 | 48.8 | −4.6 | ..... | ..... | ..... | ..... | ..... | ..... |
| 2. 16.1 miles. | Low water. | 594 | 768 | +174 | +29.3 | 14 802 | 23 159 | + 8 297 | +56.8 | 23.4 | 28.9 | +5.5 | 39.2 | 47.7 | + 8.5 | ..... | ..... | ..... |
| | Bank-full. | 880 | 1 059 | +220 | +27.6 | 40 668 | 55 925 | +15 257 | +37.5 | 47.7 | 52.0 | +4.3 | ..... | ..... | ..... | 38.9 | 42.0 | +3.1 |
| 3. 7.1 miles. | Low water | 546 | 741 | +195 | +35.7 | 14 208 | 26 138 | +11 695 | +84.0 | 25.5 | 34 7 | +9.2 | 41.4 | 56.6 | +15.2 | ..... | ..... | ..... |
| | Bank-full. | 713 | 988 | +270 | +37.9 | 39 241 | 50 702 | +18 461 | +57.3 | 44.7 | 51.3 | +6.6 | ..... | ..... | ..... | 30.8 | 33.8 | +3.0 |
| 4. 6.2 miles. | Low water. | 399 | 555 | +156 | +39.1 | 10 327 | 16 233 | + 5 906 | +57.2 | 25.9 | 29.3 | +3.4 | 39.5 | 44.8 | + 5.3 | ..... | ..... | ..... |
| | Bank-full. | 535 | 717 | +182 | +34.0 | 29 109 | 39 250 | +10 141 | +45.9 | 41.5 | 45.1 | +3.6 | ..... | ..... | ..... | 27.5 | 29.3 | +1.8 |

survey there were no levees on either side of the river, and this condition existed for 22 years, when effective levees were completed on both sides of the stream. These levees were effective during the great flood of 1903 and the succeeding years, with the exception of somewhat less than 1 mile, which was partially open on one side at the lower end. Here, the enlargement shown reaches the maximum, and the process is evidently not yet completed. Individual sections show changes amounting to double in width, eight times in area, and an increase of 80 ft. in depth.

In Reach 4, which covers 6.2 miles of river, there were no levees at the time of the first survey, and only the left bank levee was effective during the floods of 1903 and subsequent years. This one levee, effective during a great flood, began the process of enlargement, but it is still much smaller than the reaches above it.

The results seem to indicate clearly that the levees are responsible for the enlargement of the stream by confining to one channel the waters that were once dissipated by flowing over the banks and escaping through outlet bayous. Here is a direct and positive measure of the influence of levees in enlarging the bed of a stream of no mean capacity.

It seems to be clear, also, from the results in the upper reach, that the volume to be carried needs a bed having a bank-full cross-section of about 56 000 sq. ft., and when the enlarging bed reaches such proportions further enlargement is confined mainly to a comparatively slight abrasion of the banks. The deep irregular pools fill up, and the tendency is toward a stream more uniform in section and practically stable in its regimen.

As the levee system along the left bank of the Mississippi River is carried down stream toward the present connection, through "Old River," with the Atchafalaya River, and as the deposits at the entrance of "Old River" continue to increase year by year, the contribution to the Atchafalaya from the floods of the Mississippi will naturally diminish. This, together with the stable condition of Reach 1 for so many years, suggests that there is very little danger of the great river taking the Atchafalaya route to the Gulf of Mexico.

The writer is indebted to Frank M. Kerr, M. Am. Soc. C. E., Chief State Engineer of Louisiana, for statistics as to levee construction along the Atchafalaya River.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## SEWAGE DISPOSAL.

An Informal Discussion at the Annual Convention, June 28th, 1906.*

SUBJECT FOR DISCUSSION:

"The Advance in Sewage Disposal."

BY MESSRS. JOHN W. ALVORD, JOHN H. GREGORY, H. W. CLARK AND C-E. A. WINSLOW.

JOHN W. ALVORD, M. AM. SOC. C. E.—The speaker has been very much interested in Mr. Whipple's exhaustive statement of the present status of sewage purification. In a careful examination of the history of the art, made recently, it has been somewhat illuminating to see how many times things supposed to have been recently discovered had been discovered long before, and sometimes several times before. Mr. Alvord

Looking back along many of the lines of thought commonly supposed to be original with recent minds, it will be found, often most unexpectedly, that somebody, with great manifestation of joy, has thought that thought before, and written and talked about it, often with a great deal of interest, and often with a great deal of value to his time and place.

To take an example: Perhaps not everyone of those interested in sewage disposal has known of the work of Dr. Alexander Mueller, who, about 1869 or 1870, was City Chemist of Berlin. Dr. Mueller was very much interested in sewage disposal; he made important experiments, and developed the idea that the dissolution of organic solids is initiated by small, leaven-like organisms, the character and

*Continued from August *Proceedings*.

Mr. Alvord. habitat of which he studied experimentally. Dr. Mueller published an account of those experiments, and described bacterial action in language very closely resembling some of that used in recent literature on the subject.

Coming down a little further: Mr. Louis Mouras, a Frenchman, made a sort of re-discovery of Dr. Mueller's discovery, and succeeded in finding a friend who had imagination and a journal, and there may be found his ideas of bacterial ferment described in very clear language—language which resembles that used in the descriptions written in recent years by Mr. Scott Moncrieff, Professor Dibdin and Dr. Rideal, on the same subject.

Mr. Mouras had an opportunity to try his invention extensively in Paris, and with quite a good deal of success. Then Signor Paglioni, in Italy, seems to have picked up the same line of thought, and worked at it; and Col. George E. Waring, Jr., in America, seems to have been early in the field; and, even in England, Sir Henry Austin, as far back as 1852, described apparatus for the purification of sewage, and the different stages of reduction, in language which is quite readable to-day, and would appeal to intelligent men as being in line with much that has been written recently.

And so it is seen that this is really a very old subject, one that has been worked over by a great many minds, in many places, and at many times, and to-day we are joyfully re-discovering a great many things which have been somewhat well discovered before.

At the same time, there is one interesting episode, which develops from a study of the history of the art, which is impressive, and that is the fact that it is possible for the thought of the time to be led away from the best lines of development by misdirection.

The discoverers who have been mentioned developed their ideas about innate bacterial action in the infancy of the era of bacterial thought, and even prior to its general acceptance; and while it is now considered that their work was along right lines, their ideas, although published, were not always absorbed into the active discussion of the time, or, where discussed, often failed to impress their importance properly upon the majority of contemporary minds. Thus, curiously enough, as one looks back upon it, there came into use, contemporaneously with the rise of bacterial discovery and the positive knowledge that the organic solids and organic solutions are reduced by bacterial action, a diametrically opposite method of dealing with sewage, which set back the advancement of this art at least twenty years.

This curious retro-action was caused by the enthusiastic introduction of antiseptics in the disposal of organic waste. The idea of introducing processes, which have the practical effect of tem-

porarily checking bacterial life in sewage rapidly gained ground. In this way the ordinary reductions of Nature, such as we see going on everywhere under our eyes, in the fields and in the forests, were, in sewage disposal plants, temporarily stopped and postponed, with no very great apparent advantage. Mr. Alvord.

Thus, along with some of the best thought in this line of work, and in the very inception of the bacterial era, came a retro-active influence in the art of sewage purification which reduced the practical value of good ideas to a small, but working, minority, and time only slowly vindicated the work of those who at an early date had positively identified innate bacterial life as the active agent in the reduction of organic wastes.

For a long time those in the minority, whose work was so little appreciated, were obliged to wait until, by the advancement of the art, the important facts which had been previously pointed out and placed on record had been generally accepted.

It may be well enough, in the common interest of science, to discover and re-discover things which have been well discovered before, but it is far better not to lose sight of any scientific advancement, however slight or insignificant, which has once been placed on record. The history of the art of sewage purification is a curious instance of where proper advancement has been made, recorded and discussed, and then, for almost a generation, lost sight of by misdirected thought.

It must always be borne in mind that there is this danger, that the majority, as a body, may lose sight of valuable ideas—ideas which lie at the foundation of all advancement.

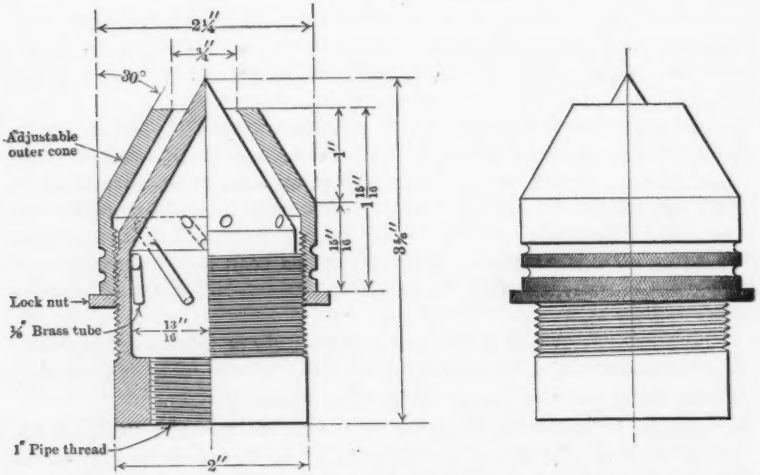
JOHN H. GREGORY, ASSOC. M. AM. SOC. C. E.—Mr. Whipple has given so clear a description of a sprinkling filter, as applied to the purification of sewage, that little further need be added regarding purification of sewage, that little further need be added regarding to one very important consideration, namely, the distribution or application of the sewage on the surface of the filter. Mr. Gregory.

In England two methods of application are in use: One by means of a movable mechanical distributor operating on a track just above the surface of the filter, and the other by a series of fixed distribution pipes with nozzles at frequent intervals through which the sewage is sprayed upon the filter, the two methods apparently giving equally satisfactory results.

It is not the speaker's intention to discuss at length the relative merits of the two methods, but it may not be amiss to say that in localities where the winters are long and cold, or where there are extended periods of cold weather, it is probable that the movable mechanical distributor would not give satisfactory results, due to trouble caused by ice and snow. Under such conditions a properly

Mr. Gregory. designed system of distribution pipes with sprinkling nozzles would be preferable.

In 1904 and 1905 the City of Columbus, Ohio, carried on an extensive series of experimental investigations on the purification of sewage, at a testing station especially constructed for the purpose, and among the devices investigated were a number of sprinkling filters. Various methods of applying the sewage to the filters were tried, and, without going into details of the methods which were found unsatisfactory, it will suffice to say that a sprinkling nozzle designed under the direction of Mr. George A. Johnson, Engineer




SPRINKLING NOZZLE USED AT SEWAGE TESTING STATION, COLUMBUS, OHIO.

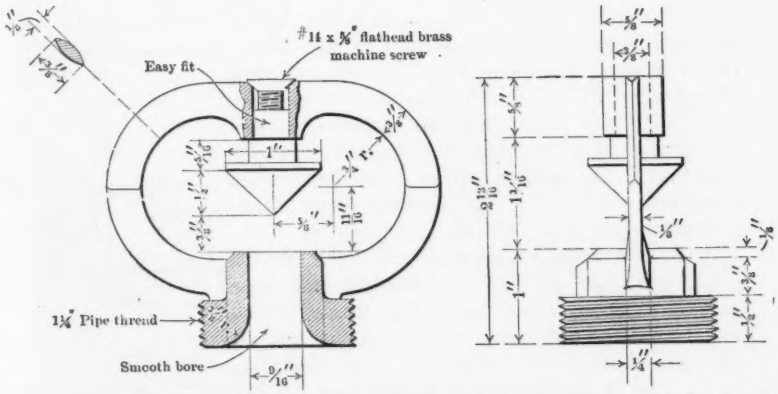
FIG. 1.

in Charge of the experimental investigations at the testing station, was finally adopted as giving the best results. This nozzle is shown in detail in Fig. 1.

The nozzle consists of an inner 60° hollow cone, 2 in. in outside diameter, and tapped at the base for 1-in. pipe. Threaded upon this inner hollow cone is an outer 60° hollow cone, the outer cone being adjustable and held in position by a lock-nut. Eight ⅛-in. brass pipes pierce the shell of the inner cone, projecting inward at an angle of 45° with the vertical. The sewage is discharged through these eight pipes into the adjustable space between the inner and outer cones, leaving the outer cone in a tangential direction at the

top. On leaving the nozzle, the sewage for a short distance remains in the form of a thin sheet, and then breaks into a spray of fine drops, falling upon the filter on the surface included between two concentric circles. Under normal conditions, the nozzle discharges under a head of 4 ft., measured at its base, and when thus operating 70% of the surface of the filter tributary to the nozzle (43.5 sq. ft.) was wetted by the spray in a satisfactory manner. There is, however, one serious objection to the nozzle, in that the orifices clog, and, although the sewage at the testing station was screened, the nozzle had to be cleaned once or twice each day. Mr. Gregory.

The successful operation of the sprinkling filters at the testing station led to their adoption in the sewage purification works now under construction in Columbus. These filters will have an area




SPRINKLING NOZZLE ADOPTED FOR SEWAGE PURIFICATION WORKS, COLUMBUS, OHIO.

FIG. 2.

of 10 acres, the sewage being sprayed through 2 108 sprinkling nozzles, spaced 15 ft. 4 in. from center to center. From the experience gained with the nozzle used at the testing station, in order that the maintenance at the permanent works might be reduced to a minimum, it was evident that a nozzle must be designed which would be free from clogging. An extended study of many types of nozzles was made, under the direction of the speaker, from which it was concluded that one having a single orifice would be the most suitable, as being least likely to clog. A series of tests was made with an experimental device, the result of which was the sprinkling nozzle shown in Fig. 2, which has been included in the contract for the permanent works.

Mr. Gregory.

The nozzle, which is of brass, consists of a single orifice, $\frac{9}{16}$ in. in diameter, with rounded edges, above which, held by two thin arms, is an inverted 90° cone, the axis of the cone coinciding with the axis of the orifice. The jet, on leaving the orifice, impinges against the cone and is transformed into a thin sheet, spreading out radially and breaking into a shower of fine drops. At the points where the sheet strikes the arms, the latter are ground down to sharp edges on each side, thereby permitting the sheet to heal up entirely after passing them. Under normal conditions in the permanent works, the nozzles will be required to discharge about 13.1 gal. per min. A series of experiments was made with one of these nozzles, and it was found that by varying the head from a minimum of 2.75 ft. and a discharge of 10 gal. per min. to a maximum of 5.0 ft. and a discharge of 13.5 gal. per min., 77% of the surface of the filter which will be tributary to each nozzle in the permanent works (206.6 sq. ft.) was covered in a perfectly satisfactory manner. In these figures no allowance is made for the effect of wind, but, on a large unprotected area, the effect of the wind will be such as to increase materially the percentage of surface covered. The principal advantages of the nozzle are: Its simplicity, the single orifice, freedom from clogging, small head, satisfactory spray, large percentage of area covered, and low cost.

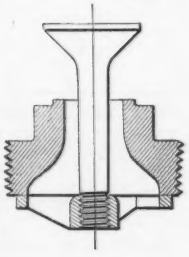
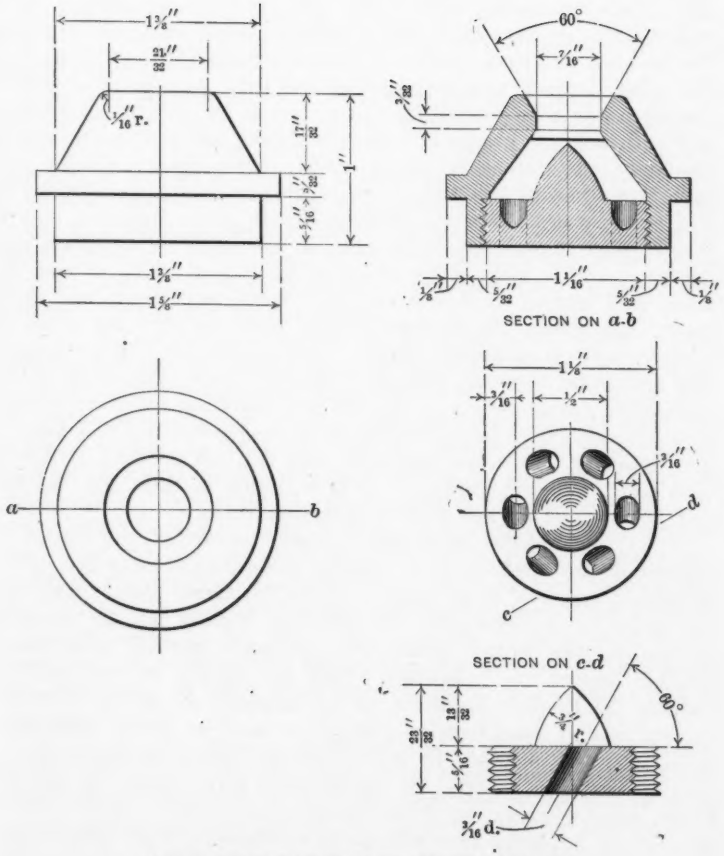


FIG. 3.

Another type of nozzle which received careful study is shown in Fig. 3. Although this type may have some advantages, the single orifice was considered preferable to an annular one, on account of its greater freedom from clogging.

In Fig. 4 is shown the nozzle used at Salford, England. As will be seen, it is in some respects similar to the one used at the testing station, and, from a few experiments, it was found that its action was very similar. Both the Salford and the testing station nozzles require a greater head than the nozzle adopted for the purification works, when operating under similar conditions, the spray from them, however, breaking possibly into slightly smaller drops.

The subject of sprinkling nozzles is not only of great interest, but of great importance, as the efficiency of a sprinkling filter, where nozzles are used for distributing the sewage, is in a large measure dependent on their satisfactory operation. The speaker is at present arranging for another series of experiments on modifications of the sprinkling nozzle adopted for the Columbus sewage purification works, and should the results warrant, he hopes to present them at some future time.




SPRINKLING NOZZLE USED AT SALFORD, ENGLAND.

FIG. 4.

Mr. Clark. H. W. CLARK,* ESQ. (by letter).—That the study of sewage purification is a fascinating one, can only be comprehended adequately by those who are actually engaged in it. Of the two branches of this study, namely, theory and practice, or why and how, sometimes one and sometimes the other plays the more prominent part in the mind of the investigator. Because of the work resulting in what Mr. Whipple rightly terms "The mist of confused notions about septic tanks, contact beds, and trickling filters," etc., which during the past ten or fifteen years has been prominent in the literature of the subject, much true information has been gained. The subject cannot possibly be studied by many men under different conditions and with different grades of sewage without conflicting ideas arising and opposing statements being made. Each honest opinion and each honest result has had its value, however, and, by comparison and elimination, the truth is being slowly made manifest. There is a certain impatience, to be sure, in the mind of the practicing engineer who is looking for absolute data upon which to base his plans, and instead of this is, perhaps, forced to compare and study many apparently conflicting results obtained by the work of many people at different places. Those chemists, bacteriologists and engineers, however, who have given months and years to experimental investigation of the subject, have an infinite patience with all apparently contradictory work, understanding full well its real difficulty. As a general rule, they are not carping critics of each other, although perhaps stoutly believing in their own theories and results, and always willing to defend them.

It is undoubtedly true that England is to-day the center of activity in the construction of sewage purification plants and of experiments upon a large scale. Many of these plants, however, are based upon principles and theories worked out in America during the past twenty years, as is willingly testified to by many English experts and engineers. This can readily be confirmed by reading the English literature on the subject. At the present day, leaving out of consideration sewage farming or broad irrigation, there are three methods by which sewage can be treated more or less successfully, namely, by intermittent sand filters, by contact filters, and by sprinkling filters. Much more work has been done in America in studying intermittent sand filtration than in studying the other two methods, and the reason, of course, is clear. The home of sewage purification in America up to the present time has been New England, and intermittent sand filters are easily and cheaply constructed there, and, for the problems so far presented, are more satisfactory than the other kinds could possibly be. During the past ten years, however, both contact filters and trickling filters

* Chemist, Massachusetts State Board of Health.

have been investigated at the Lawrence Experiment Station, and, during the past two or three years, at other experiment stations. Of these two latter methods of filtration, the trickling filter easily takes the first place. Properly constructed and operated, contact filters when built of rough material can undoubtedly give more or less efficient results, but their life between thorough cleanings is comparatively short unless the sewage applied receives good preliminary treatment, and their rate per acre is much less than that of trickling filters. Mr. Clark.

Trickling filters have been operated at Lawrence since 1899, and, indeed, the first filters at Lawrence operated in a manner similar to the modern trickling filters were Filters Nos. 15 and 16, put into operation more than fourteen years ago. As well stated by Mr. Fuller and Mr. Johnson in the Columbus report, also in the report of the engineers of the Baltimore Sewerage Commission, and as acknowledged by many English experts, these filters, constructed of stone and operated at high rates, were the forerunners of the trickling filter of the present day.

What can be done by sand filtration is fairly well known at the present time, and also about how permanent such filters are when operated under normal conditions. There is no need to quote here the review made by the writer in the report of the Lawrence Experiment Station for 1904, showing the work of many years of both experimental and municipal sand filters in the purification of sewage and in the storage of organic matter. It was evident, however, from this review that, with the experiment station sewage, about 50% of the nitrogen applied during eighteen years was oxidized; about 15% appeared in an unoxidized form in the effluents; about 35% was unaccounted for, and not more than 4 or 5% remained stored in the sand. Leaving out of consideration the upper 6 in. of material, the filters receiving this sewage were in as good condition at the end of this period as when first put into operation.

At the municipal areas in Massachusetts, most of which receive fresher sewage than that received at the experiment station, a very much larger percentage of the organic matter in the sewage is removed mechanically by settling tanks or by raking and scraping the surface of the beds, and a very much smaller percentage is oxidized than is the case with the Lawrence experimental filters. At these areas, for instance, only an average of about 25% of the applied nitrogen is oxidized and appears in the filter effluents; about 15% appears unoxidized in the effluents, and the amount stored in the filter, removed from the surface by raking and scraping, or escaping by liberation into the air, amounts to about 60 per cent. Of this 60% by far the larger proportion is removed by settling, raking and scraping.

Mr. Clark. In this review, the writer called attention, moreover, to a fact that generally has been overlooked, namely, that the matter stored in sand filters is largely carbonaceous rather than nitrogenous. As a matter of fact, only 4 or 5% of the organic matter stored in the Lawrence sand filters after seventeen years' use was nitrogen.

There is no question of the efficiency of sand filters, neither can there be any question that the effluent produced by them is of much greater purity than can be produced by any other kind of filtration known at the present time. Neither is there any question at the present day regarding their practical permanency, nor is there any question of their cheapness of operation, considering the results obtained. Different geological and other conditions, however, require and will require at many places in America other methods of sewage purification, and for such locations the trickling filter is now the most prominent and promising method. It is fairly well known at the present time what trickling filters will do under ordinary conditions and with different depths of filtering material. With sewage as strong as that in use at the Lawrence Experiment Station, and with deep filters, rates of from 2 000 000 to 3 000 000 gal. per acre per day can be obtained, and high nitrification and the production of a non-putrescible effluent will ensue. The degree of permanency of these filters is something about which more is being learned every day, but as yet they have not been operated long enough, either in America experimentally, or abroad practically, to be absolutely certain of the length of time that they will run under different conditions before thorough cleaning will become necessary. However, the chief filters of this class at Lawrence have been in operation now for more than seven years without the accumulation of enough matter to cause trouble; in fact, the slight accumulation so far made probably has rendered them more efficient. During these seven years less than 2½% of the total organic matter applied to them, and only about 1% of the applied nitrogen, has as yet been stored. In distinction from this, contact filters at Lawrence, constructed of the same kind and grade of material, and operated at only about one-fourth the rate of these sprinkling filters, have stored, in a period of operation less than one-half as long, 24% of the total applied organic matter and 9% of the applied nitrogen and have produced very poor effluents. Contact filters of clinker and coke have been operated for many years at Lawrence, and have given much better results than the broken-stone filters just referred to, and especially so when the sewage applied has been given an efficient preliminary treatment. Two such filters, 5 ft. in depth, have been in operation for more than six years, and at the present time receive sewage at the rate of a little less than 500 000 gal. per acre per day.

Mr. Clark.

When the effluents of trickling or contact filters are compared with the effluents of sand filters, the real difference is indeed shown. The effluent of the average sand filter is generally clear, free from turbidity, odorless, and often can fairly be called sparkling. The effluents of the best contact and trickling filters, on the other hand, are generally more or less turbid and unattractive. Such effluents as are given by the best of these filters at Lawrence, however, are non-putrescible; even the effluent of a poorer filter becoming so when the matters in suspension are removed by sedimentation. Such effluents improve rather than deteriorate on keeping, and when mixed with even an equal volume of ordinary river water containing much dissolved oxygen, they improve rapidly.

In order to lessen the area necessary for the treatment of a given volume of sewage, and to improve the final effluent, preliminary treatment deserves great attention. It seems possible that screens and methods of screening may be greatly improved, and, on account of this, a more economical and efficient method be devised for removing suspended matters than settling and septic tanks, or at least be so improved that less will be left for such tanks to do. Septic tanks for the treatment of the sludge, only, after ordinary sedimentation, spoken of by Mr. Whipple as a process now being considered by English investigators, have been in use at Lawrence for the past seven years, being first described in the Lawrence report for 1899.

Finally, sand filtration is an ideal finishing process. A complete plant at the Lawrence Station, which has been in operation several years, is as follows: (1) tank treatment; (2) sprinkling filters; (3) sedimentation; and (4) sand filtration. The rate at which such a plant can be operated depends upon the grade of sewage to be purified, but, at Lawrence, rates of 2 500 000 gal. per acre for the sprinkling filters and 500 000 gal. per acre for the final sand filters can be easily maintained, with the production of a clear and highly nitrified final effluent. Such a plant has recently been recommended by the engineers of the Baltimore Sewerage Commission for the purification of Baltimore sewage.

While experiment stations can furnish reliable data as to methods of filtration, rates of filtration, and degrees of purification, they cannot, of course, give illustrations of engineering skill in design and construction, such as the works abroad present. Mr. Whipple's discussion is an interesting description of such works, and the English engineering journals have been full of such descriptions for a number of years. Adequate and reliable analytical data are now needed, in order to show what these purification plants actually accomplish—such data as have been given out from Lawrence, Columbus, and elsewhere in America.

Mr. Winslow.

C-E. A. WINSLOW,* ESQ. (by letter).—Mr. Whipple has covered the ground so thoroughly that little remains to be done except to congratulate him, and to express appreciation of the importance of so clear, complete and exhaustive an analysis of the fundamental principles of sewage treatment.

What strikes the writer most forcibly in Mr. Whipple's address is his frank recognition of the great complexity of the problem. We no longer hope, except in rare cases, to treat sewage by dumping in chemicals and discharging the supernatant liquid into the nearest stream, or by pouring it on sand beds without preliminary treatment or subsequent sludge removal. Scientific sewage treatment involves a number of distinct technical processes, each of which must be carefully regulated in order to secure the best results. The disposal of the sewage from the South Metropolitan District of Boston, for example, would require every year the conversion of 3 000 tons of nitrogen into a stable form, a problem in industrial chemistry of no mean magnitude.

There are two main phases of the sewage problem which deserve special consideration: the oxidation of organic matter and the removal of suspended solids, the first being a chemical change accomplished by bacterial action, and the second a physical change generally brought about by mechanical means. The writer believes that these two separate problems must be faced in any sewage disposal project which aims permanently to produce a clear and stable effluent. It was at one time held that, in the intermittent filtration of sewage through sand, no sludge was produced. The experience of nearly 20 years in Massachusetts has shown quite clearly that this is fallacious. At Brockton, for example, nearly 6 tons of sludge are removed from the beds for every 1 000 000 gal. of sewage filtered; and even with constant care the beds which have been in use for 10 years or more are becoming so clogged below the surface as to impair their operation seriously.

The fact should be faced that a certain quantity of solid sludge must be produced by any efficient process of sewage treatment. This sludge, however, may be reasonable in amount and comparatively innocuous in character, if the various parts of the system be properly adjusted; and the best results will generally follow from a division into preparatory processes, purification processes and finishing processes such as Mr. Whipple has outlined so clearly.

The central part of the whole system is the purification process which always consists in the conversion of unstable organic matter into some stable form: nitrates, gases, or humus-like organic compounds. Of the three chief methods of cultivating the bacteria

* Biologist-in-Charge of the Sewage Experiment Station, Massachusetts Institute of Technology.

which carry out these changes, either may prove most satisfactory in a given case. Intermittent filtration yields the best effluent, and is the cheapest method where the requisite sand areas are available. Contact beds, as Mr. Whipple has pointed out, are especially indicated where only a limited head is available, although the writer questions somewhat the statement that, in small installations, they can be made to operate with comparatively little attention. He is inclined to think that a trickling filter, properly designed, would be less seriously deranged by neglect than are many contact beds which he has seen. Mr. Winslow.

For most purposes the trickling filter offers the most satisfactory method of securing an oxidized effluent. For nearly a year Boston sewage has been treated at the Technology Experiment Station on a trickling bed having an area of 200 sq. ft., and at a rate of 2 000 000 gal. per acre per day, with excellent results. The effluent is scarcely improved in appearance or in its organic nitrogen content, and sometimes contains more suspended matter than the applied sewage. It is uniformly stable, however, and the fact that it contains so much suspended matter is the guaranty of the life of the filter. Beds of this type have the great advantages of operating at a much higher rate, and with a greater freedom from clogging, than any other form. The great practical point to be worked out in their operation is the best system of distribution, as their success depends mainly on the fineness and evenness with which the sewage can be spread over their surfaces.

Before treating Boston sewage on the trickling bed, it has been found best to remove a portion of the suspended solids by two successive preliminary treatments. The sewage treated at the Experiment Station first passes through a detritus tank containing a screen with ½-in. openings. Here the floating matter and gravel are removed. The total quantity of material taken out in this tank amounts to only 0.65 cu. yd. per 1 000 000 gal., and it is so largely inorganic as to be inoffensive when spread on the surface of the ground. Next, for the best results, the sewage is passed through septic tanks. The writer is inclined to agree with Mr. Whipple that the beneficial effect of the septic tank in relation to the sewage is simply the effect of physical settling, the only advantage of the septic process over plain sedimentation lying in the subsequent decomposition of part of the sludge. Mr. Whipple's suggestion of limiting the septic action to the sludge alone, along the line of the Hampton experiments, appears to be a logical conclusion from this position. The experiments made at Brockton a few years ago by Mr. Bolling indicated, however, that a septic tank treating concentrated sludge fills up very rapidly. The conditions which make liquefaction rapid and successful in one septic tank, and slow and

Mr. Winslow. inadequate in another, are very little understood and should be studied exhaustively. In the tanks of the Technology Experiment Station the decomposition of sludge appears to be unusually active, three-quarters of the nitrogen deposited as albuminoid ammonia being destroyed. At the same time Boston sewage readily shows the bad effect upon the effluent of a too prolonged septic action. Ill-smelling gases (hydrogen sulphide, mercaptans, etc.) are formed from the sulphates introduced by the leakage of sea-water, and the subsequent processes of purification are interfered with unless the effluent be well aerated. Therefore, the period of passage through the septic tanks has been reduced to 7 hr., so as to minimize the chemical changes in the supernatant liquid as much as possible.

The experimental septic tanks remove about half the suspended matter from Boston sewage, but in passing the effluent through the trickling beds no further reduction takes place, and, at times, there is an actual increase. In order to produce a clear effluent, it is necessary that some finishing process should follow the trickling filter; and a brief sedimentation lasting about 2 hr. is now being used. The average results for the first 3 months of 1906 showed 126 parts per million of suspended solids in the crude sewage. Septic treatment reduced this figure to 60, and, for this particular period, the trickling filter increased it again to 84. Sedimentation of the trickling effluent finally decreased the suspended solids to 40 parts. If still better results are desired, straining or chemical treatment might be tried. The writer's colleague, Mr. Phelps, is at present studying the use of lime for the production of a clear and sterile final effluent. The separation of solids may be carried to any desired point of perfection, if once the essential oxidation of organic matter has been carried out in the trickling bed.

The main point in this discussion seems to be its emphasis on the fact that sewage disposal is an engineering problem which is always difficult, and which varies in each individual case. Only expert study of local conditions, the character of the sewage to be treated, the grade of effluent desired, the filtering material, the land area, and the head available, can solve it properly.

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# PAPERS AND DISCUSSIONS.

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## ENGINEERING EDUCATION.

An Informal Discussion at the Annual Convention, June 27th, 1906.*

SUBJECTS FOR DISCUSSION.

"What is the Best Preparatory Education for the Civil Engineering Profession?"

"Is Technical Training the Best Education for Executive Work?"

BY MESSRS. BERNARD R. GREEN, EDWIN F. WENDT, A. N. TALBOT, F. R. COATES AND BASSETT JONES, JR.

BERNARD R. GREEN, M. AM. SOC. C. E.—Although the proposer of the topic for this occasion, the speaker's object was not to make an opportunity to offer ideas, but to secure an answer to the question or to arouse discussion which might lead to one. Professor Swain's views are very near to those of the speaker's, the result of a lifetime of observation over the period—so well known to the grandfather engineers of to-day—which has covered perhaps 90% of the stage of development of the science and art of civil engineering. Mr. Green.

The question of education for the engineering profession must surely be a very present one to the minds of, at least, all the older engineers. The speaker's experience began when preparatory schools were few and weak. Other than the Rensselaer Polytechnic Institute, the United States Military Academy, and two or three new, so-called scientific schools attached to classical colleges, there were

*Continued from August *Proceedings*.

Mr. Green. none. The word attached is used because these schools had so little in common with the college course proper that they might as well have been located anywhere else. The speaker took the civil engineering course at the Lawrence Scientific School, of Harvard College, in 1861, then a very small school in almost every sense, but hardly inferior to the Rensselaer Polytechnic Institute, if the student were uncommonly well prepared and industrious, for he could not graduate without passing a searching examination. Consequently, though the classes were small in numbers, hardly one-third of their members were graduated. The course consisted chiefly of drawing, the higher mathematics, and the mathematics of surveying and mechanics, with no laboratory work, except a few lessons in the use of surveying instruments, and no visits to engineering works finished or in progress. Two years of this work brought the class to graduation with the degree of S. B. Those students who had previously taken a part or the whole of a college course usually had the advantage of the others.

Entering upon work in an engineering office the speaker began to read engineering books and to review the textbooks of the school. Observed by the Chief to be thus engaged, he was encouraged to continue because, as he remarked, by reading something about engineering would be learned, but one could not thereby alone become an engineer. Due recovery from the jolt of this surprising statement followed when the speaker had had time to appreciate that no graduate of a school could possibly become a real engineer without practical experience and observation.

Since then, through life, he has endeavored to be a civil engineer, while the professional schools have developed and multiplied, and the science and art of engineering have grown to the enormous proportions of the present day; it is an amazing contemplation, whether measured by quantity, quality and territory conquered, or by scientific development, refinement and the sum of knowledge gained. This period of forty-five years has comprehended almost the whole growth from nothing to much, and made civil engineering, considered in its broad sense, a profession coequal with the highest and most dignified as well as the most indispensable to mankind. All this is naturally best realized by those engineers who have been the authors of the development, many of whom have at times regretted that they had been born so early, and have envied the advantages of younger men; but, the older men, at least, realize that the demands upon the profession have, nevertheless, outrun the schools, and that there is great need of a higher and more thorough and comprehensive character of school training than has yet been provided.

Such engineering institutions of learning are sure to come in

some way, but the day should be hastened with all safe speed. The universities are endeavoring to solve the problem, but they are hampered for means of all kinds, financial, physical and pedagogic. The recent effort to combine the Massachusetts Institute of Technology with Harvard University is most significant of what is needed for the best education of an engineer. There is much profitable thinking and discussion possible in all this matter, and immeasurably good results to be gained, as evidenced by the active existence of the Society for the Promotion of Engineering Education. Mr. Green.

Perhaps this subject is more interesting to the speaker than to engineers who have not been called upon to steer one or two sons into the profession. In due course the speaker found himself with a boy growing up, who had a decided bent for engineering, and he was given the civil engineering course at the University of Michigan. He has since been in constant practice for sixteen years. It was the best that could be done for him at that time. Now another son, with a similar bee in his bonnet, is taking the school course, but he is endeavoring to widen and perfect it by a combined college course, which until recent years was rarely done. Even now this course is too uncommon, but the universities are not economically organized for it, and few boys can afford the necessary time and expense. In the present instance the young man is so choosing the electives at Harvard University that he may secure the A. B. degree and then finish the civil engineering course at the Massachusetts Institute of Technology in two more years with a C. E. degree, a course covering six years in all. Thus he may secure the advantages of a so-called college course, with the humanities—English especially, and plenty of it—together with a pretty thorough curriculum in civil engineering proper. His aim is ultimately to become truly learned in his profession, in a broad way, and to be able to hold his own in contact with educated men and gentlemen anywhere.

This should be the training and accomplishment of every engineer. Few others can rise to the top of the profession at the present day, and the best engineering schools must be so organized, connected with the higher education in general, and equipped with a physical outfit and a manly and cultivated personnel in their teaching corps, that they may ensure to the students such training. Think of some of the professors and teachers to be found in many of the best schools of the day—kings in mathematics, wizards in chemistry, magazines of engineering facts, but no more magnetic, graceful, or sympathetic than an automaton. The professors and instructors should be sound, enthusiastic and practical men of experience, as well as scholars in the technology of the profession,

Mr. Green. and attractive gentlemen withal. What might not an ambitious and enthusiastic young student of the grand art of engineering accomplish, in his brief course at school, under the guidance of and by coming in personal contact with such teachers! How well and with what gratitude do many of us remember some one or two, of all those under whom we worked at school, as our ideals of excellence! But salaries are small—very small—and many of the teachers, and too many of the professors themselves, have had but little practical experience. The situation will be different when salaries tempt and universities insist on practical engineers with the teaching faculty and all the other qualifications necessary to those extremely important positions. The speaker suffered much in his school from lack of excellent teachers—although Professor Eustis, as the head of it, was ideal—but the members of the class were quite sure that one of his assistants learned much more about mathematics from them than they did from him.

The engineer of the present day occupies an enormously important and responsible place in the world which is constantly demanding more and more of him at his best. Engineering undertakings are increasing in number, magnitude and complexity. At first, engaged in the ingenious application of skill and the knowledge of materials and physical forces, in a few isolated places and in a small way; then in a wider extension of this skill and of mechanical development; and at last in the application of still higher principles of engineering science, in the world-wide relations of engineering to almost all interests of mankind, this has been the scope of the profession of the civil engineer.

How should the boy and the student engineer be trained by the university in this day and generation? That is the question, and it needs a much more definite answer than has yet been presented. Each father, especially if he be an engineer himself, is endeavoring to determine this for his son by selecting from the various schools that course, both mental and manual, which may accomplish the best results for his own particular boy in the few years—four to six—which can be afforded for it, to the end that he shall acquire a good knowledge of history, literature and language, of how to think and study and investigate, of how to speak and write, and a habit of general reading, as well as a knowledge of the technics of the profession.

Students to attain this end must come from good family influences and be healthy, interested and assiduous. The engineer should be refined, brave, self-reliant, ready with clear-cut ideas and good English in speaking and writing, and thus be able to make an effective appearance, and to give a good account of himself before any board, committee, or individual, at any moment. Such

men command respect, a hearing and then, very often, the whole situation. Mr. Green.

The young civil engineer should strive to learn and to become familiar with mechanical operations of all kinds and with their approximate costs, matters that may be learned by observation during the school period and immediately afterward. He should particularly learn how to judge of and to treat and handle men properly. In short, he cannot possibly learn too much, or become too skilled in anything, the physical sciences, law, literature, history, modern languages, mathematics, the technics and practice of the numerous branches of engineering, and, especially, in the fine arts, that he may never walk nor work without a present sense of the beautiful—of the graces and harmonies of things. In his student days he need never fear that any item of knowledge or skill which he may acquire, from milking a cow to analyzing a bridge truss, or singing a solo, will ever come amiss, whether it seems to pertain to his profession or not.

The engineer's business is world wide, comprehending an infinite variety of applications, places, peoples and human interests. He may have to go anywhere at a minute's notice, travel widely and find himself in contact with numerous conditions calling for all the knowledge, tact and practical skill that he may possess.

Engineering literature, descriptive or critical, of undertakings or accomplished works, or of the experiences of difficult construction, is thin and scarce. Engineers have not written enough, do not write well enough, and do not like to write because they do not know how. This is because of the insufficient training of the past generation, which prevented ease and fluency in writing, by one intensely engaged in practical work. Consequently, many valuable experiences and ingenious accomplishments, which might have been invaluable to others and to the world, have lived and died in the minds and memories of the engineer geniuses, to whom the labor of concise and readable records was irksome and laborious.

The engineer who can stand before a lay committee of business men and explain his plan attractively and concisely, showing thorough familiarity with the subject—for hard-headed business men are pretty acute judges—is more likely to get the job than one who, though knowing it thoroughly, presents it badly.

This general question of engineering education has been brought more forcibly to the speaker's mind by the recent organization of the Washington College of Engineering under the George Washington University. Its location and prospects are most favorable, and the college already has some 200 students. In its interest, as a trustee, the speaker recently accompanied a committee of inquiry and inspection to five of the leading engineering schools of the

Mr. Green. Eastern States. All were found to be more or less overcrowded with students in the laboratories and drafting-rooms, and to need more space, more teachers and more of everything requisite to good work. Some schools appear to overdo in laboratory work, to the detriment of fundamental principles, and others to err in the opposite direction. The necessity of a consensus of practice was noticeable, such as may possibly result from the deliberations of the Society for the Promotion of Engineering Education, recently organized.

Engineering, in the general sense, now occupies more than half of the whole field of education for professional life, and all the schools devoted to it are filled, even to crowding, with students. It is easy to see the condition and trend of the times. The age of applied science has but begun. Research, keen competition in ingenuity and the mechanical performance of the world's work, the growing appreciation of public art and its recognition in engineering works, are rapidly absorbing the attention of the whole world, and it is all the engineer's business. He is involved in it everywhere, and the character and quality of the work, and its general effect for the good of the community and of the world at large, will depend on the character and quality of the engineer. As heretofore, but more than ever at the present time, the material, and, in a great degree, even the art world, depends on the engineer, and cannot get on without him.

How indispensable, therefore, his proper training and education! With what care and consideration should he not be selected, trained and launched into his work! He spends the people's money, and, in the construction of permanent and necessarily costly works, transforms topography and determines largely the permanent taxes and the cost of the future maintenance of the property. He cannot know too much, nor be too well-grounded in his profession.

Therefore is it important to consider and determine, as engineers are accustomed to do, what is the best course, and how much preparatory or school education is necessary for the professional civil engineer, and how it may be most effectively and economically obtained.

The speaker thinks it is a subject of immediate and proper concern for this Society, which should take it up for active consideration and determination in co-operation with professional educators at large.

Mr. Wendt. Edwin F. Wendt, M. Am. Soc. C. E.—In discussing the question, "What is the Best Preparatory Education for the Civil Engineering Profession?" a previous speaker commented on the fact that the American college or university does not seem to aim to educate young men to be gentlemen. This remark suggests that Ruskin

at one time made the statement that the object of the English university was to turn out both scholars and gentlemen. The American university, apparently, makes no direct effort to turn out more than scholars, but it should be the object of every American school of civil engineering to graduate young men who are gentlemen as well as scholars. Mr. Wendt.

The education of the young man who expects to be a civil engineer should be most thorough and comprehensive. A good common school education is essential. The college course which gives the greatest and most thorough training is probably that which leads to the degree of A. B. Having received this degree, the student of civil engineering should enter a technical college and complete the special course which is related to his future profession. After the completion of the courses of the common American college and the technical institution the young civil engineer should be placed in an office where he may become acquainted with the methods pertaining to the design and execution of engineering work. A student can afford to accept such a position, even without compensation, in order to become acquainted with the routine of work. Without this knowledge, a graduate is unable to apply his education to a useful purpose. While the student is getting all this preliminary education, he will find it greatly to his advantage to obtain during the summer vacation a position on an engineering corps, which will bring him in contact with field work, in order that he may become acquainted with the routine of the field as well as the office. Such positions are hard to obtain, and the wise student will endeavor to get an opportunity of this character even if the compensation should be only sufficient to cover expenses. The ambitious student, who is willing to work at a small compensation in order to gain this valuable experience, will always be able to get the desired opportunity.

The second question under discussion: "Is Technical Education the Best Training for Executive Work?" does not seem to be well stated. It should read, "Should Technical Training Form a Part of One's Education for Executive Work?" An affirmative answer, only, can be given to this question. In former times civil engineers who became executives generally failed to get this technical training. Such schools were not numerous, and their location was at a distance, so that not many young men could bear the expense of pursuing a course in a technical institution. At the present time, however, these institutions are quite numerous, and are well located geographically, so that a technical education is within the reach of a large proportion of college men.

Competition, among civil engineers who desire executive positions, is very keen at the present time, and experience seems to indi-

Mr. Wendt. cate that the man who possesses a technical education will advance more rapidly than the man who does not. The successful management of the business of the large corporations of the present day depends upon the judgment of the executive officers, and the man who possesses technical as well as practical knowledge should possess the best judgment, and, therefore, ought to be well qualified for executive work.

The time is not far distant when a large majority of the executive positions in the business world will be occupied by men who have had a technical education.

After all this has been said, the fact remains, that many of the men occupying executive positions in the United States have not received any technical education. They entered business life early, studied human nature, and gradually became well fitted for handling men. Experience was gained day by day in the practical school of business, and such men have been very successful. The boy who obtains a technical education should outstrip the one who is not so fortunate, but, if he does not possess a knowledge of human nature, he will become a very poor executive, no matter how thorough his education. Executives, like poets, are born, not made. Those possessing technical education as well as practical experience should be more efficient than those possessing technical education only.

Mr. Talbot. A. N. Talbot, M. Am. Soc. C. E.—Mr. Green has referred to the importance of this topic, and has expressed the desire that the Society give it further attention. Professor Landreth has mentioned the Society for the Promotion of Engineering Education, which society has become a vigorous one. Its policy for the past few years has been to hold its annual meeting in connection with some engineering society. Three years ago there was a joint session at Niagara Falls with the American Institute of Electrical Engineers, resulting in a very interesting discussion and excellent papers, from the standpoint of the engineer and of the educator, on the subject of Engineering Education. In 1905 the meeting with the American Society for Testing Materials was productive of much good. This year it will meet with the American Association for the Advancement of Science.

In the past, the Society for the Promotion of Engineering Education has not been able to make arrangements for a joint session with the American Society of Civil Engineers. It seems to the speaker that much would be gained in a discussion of the requirements and needs of Engineering Education by having a session of this Society in connection with the Society for the Promotion of Engineering Education, and it is suggested that arrangements be made for the consideration of educational topics at a meeting of this kind.

F. R. COATES, ASSOC. M. AM. SOC. C. E.—In a book published by E. H. McHenry, M. Am. Soc. C. E., several years ago, the following definition is given: "Engineering is the art of making a dollar earn the most interest." In a great many instances engineers do not pay enough attention to this, and the failure of a number of men in the profession is distinctly attributable to the fact that, instead of following Mr. McHenry's definition, they controvert the same and make it read as follows: "Engineering is the art of making a dollar go the quickest." Mr. Coates.

In order to obviate this, the young engineer should acquire, at the proper time, a commercial and financial training, as applied to his profession. He should also have instilled into him the practical side of engineering—a theorist will never be a success as an engineer. By the time that he has completed his four years' course at college, he should have determined the special branch of engineering which he is going to follow; then he should connect himself with a company where he can get two years' field work, then a year in the drafting-room, followed by another year in the field. After this, in order to broaden himself, he should become associated with a contracting company for two or three years. During his connection with the latter, he will have impressed upon him, to the fullest degree, that Mr. McHenry's definition of engineering is about correct.

A man who follows this course, will find that, at the end of the time thus spent, he will be thoroughly qualified to be placed in responsible charge of work.

While on the subject of the "technical training of an engineer," one point should be emphasized, and that is in connection with engineering instruction in colleges and universities. A thorough course in maintenance engineering should be given to those students who intend to follow railroading. This department needs special care and attention, as it is one in which money can be saved or wasted very rapidly. A great deal of practical work is needed by the engineer who follows this branch, but it opens up a large field, and, at present, the practically trained engineer of maintenance is a scarcity.

BASSETT JONES, JR., ESQ. (by letter).—The essential thing in education is to give the student, as Mr. Swain says, "the ability to think clearly and logically," but before this can be done there must be aroused in the student an interest in clear thinking, or, which is the same thing, in logic. Logic is the empirical science of thought, in the same sense that biology is the empirical science of organic activities, or that mechanics is the empirical science of moving masses. The writer would thus distinguish sharply between philosophy and the empirical sciences of so-called given facts, which, in reality, Mr. Jones.

Mr. Jones.

go no deeper than the facts themselves, and which, as such, teach nothing of the actual internal structure of the world. Such sciences are the sciences of "the world of description," and, as this term implies, merely serve to translate into terms of thought what experience of this world finds to be facts. They are adequate only as a means of unifying the common experience of many individuals. That this is so, is easily shown, for who among men has really experienced, for instance, the law of gravitation? Who can say that such a law really exists? Of course, it is only an approximate description of one small fragment of our social experiences, and serves only to describe in what order these experiences may be expected to take place. The law itself is valid only as far as our experience now goes, and never states any deep truth as to the nature of facts, the behavior of which it may thus be said to describe.

It is easy to say that such considerations as these are not "practical." Engineering does not attempt to go behind the scenes. It is satisfied to do what it can in dealing with the world as science finds it, and in putting into concrete shape those laws which the abstract scientist states as adequately describing, for practical purposes, the various activities of Nature. But here is the point. What are these practical purposes? Are they no more than a blind groping after something unknown? How can we grope for something of which we know nothing? Is life after all such a game of pure chance that we may be likened to blind men seeking for the light? If we know nothing of that for which we search, then indeed we could not even know that it existed, and then, pray, whence the search? But if we do know that, somehow, and sometime, the purposes of this life are fulfilled, and if, therefore, we know that this fulfillment has real being, then let us pause to ask ourselves how we know so much, and whence comes our knowledge. Such an inquiry must give us a standard by which to gauge our purposes, and thus only can we learn how we ought to live in order that our life may be given some real value.

Does it not appear on the face of it, that what an education, at least, ought to do for us is to teach us how to estimate and judge life? If the student knows nothing of the chief business that is to engage his efforts, namely the business of living, then how is he, first of all, to select for himself a proper field for his endeavors, and how, when he has found his opportunities, is he to make the best of them? Does the engineer lay the cornerstone before every detail of the structure has been worked out? Then, how wise is it for a man to begin life not knowing what he ought to do next, and without any definite plan and purpose in hand.

It will be claimed, and with some justice, that it is just here that professional education has the advantage over classical train-

ing, inasmuch as it gives the student a definite plan in life—a means of gaining his livelihood, and an interest which should color the world for him with a meaning which it could not otherwise have. But does it not appear at once that the world is not the field for any special training alone? The world is not all manifestations of the validity of electrical theory, any more than it is the field in which the theories of statics alone hold sway. It is the manifestation of conscious life, and as such it should be studied. That for an individual the laws of thermo-dynamics possess a particular interest is no reason that, for him, the world should be only a huge case of the applicability of certain differential equations. The writer has been with men who were dead to facts, and, as far as he could make out, dead to themselves, unless they stood in the presence of certain types of machinery. Such men are not intelligent beings, they are neither selves nor individuals. It seems to the writer that rather than be like that, it would almost be better not to be at all. Mr. Jones.

It is easy enough to say that no knowledge but useful knowledge should be taught, but that depends on what is meant by "useful." A man's life may be so narrow that very little knowledge will be useful to him outside of one or two subjects, and, again, a man's life may be so broad that he will find some application for nearly all knowledge. In fact, knowledge is never the criterion; it is always life. Then the question naturally arises, for what is any knowledge useful? Is it useful only as a means of gaining a livelihood—"to fill the till and the larder?" Then, are we no better than the beasts of the field? Is knowledge only of value as a foundation for constructive achievement? Alas, all this we must leave behind us, unless, indeed, it is torn down and superseded ere we go. Yes, you say, but each thing done is something added, and lives again in what comes after. But if the small fragment of my purposes which I leave behind me embodied on this earth is all that is to give real significance to my being, then indeed how wasted is my life and struggle for self expression, for do not the heavens show us how relatively short-lived is even this little planet of ours?

The acquiring of knowledge has never been able to halt at the point where knowledge ceases to be purely utilitarian.

"Natural knowledge in desiring to ascertain the laws of comfort has been driven to ascertain the laws of conduct, and so to lay the foundation for morality."*

All knowledge is useful if rational, that is, if the facts are in harmony with the deepest purposes expressed in the world. "A thing is useful," says Plato, "if it is sought after with a view to the beautiful and the good; but if pursued in any other spirit, useless." "If facts are irrational, and therefore of no value in establishing

* Huxley, "Advisableness of Improving Natural Knowledge."

Mr. Jones. principles of conduct, which is the chief use of facts," they are useless. The facts of my life are to teach me how to live, and the richer my life, the larger the body of organized facts that are needed to make up my knowledge. But the word "organized" must be used with circumspection, for there is no fact discoverable in this world that bears no relation to any other fact whatsoever. No fact is utterly independent of the rest of the world. Such an independent fact would be a complete anomaly. When we speak of organized facts we mean those facts which are the organized part of a given life purpose. Thus, if it is my purpose in life to be a botanist, the discoverable facts of plant growth, behavior, and variations are thereby found by me and organized in my attempts to interpret consciously their meaning. If this purpose, namely, to be a botanist, were my sole purpose in life, then indeed would all other facts, in so far as they bore no definite relations to the study of plants, fade into insignificance, and would be classed by me as "useless." But it is necessary here to note that a life devoted so exclusively to one class of facts would be utterly impossible, for no one aspect of our complex world could be thus separated and treated, without consideration for the remainder. Such simple-purposed lives are found only in the lowest animals, where, for instance, the obtaining of food seems to be the only actuating principle.

We are limited, however, by our own stage of finite consciousness, to an attention which can only grasp relatively little of the world. This is because we fail to find more than a relatively narrow purpose in life, but, however barren our existence may seem, better and more complete purposes are always evolving with the progress of conscious life toward a fulfillment which, of course, we can never hope to find in this temporal world or in this stage of being. But that this fulfillment is, we have good warrant for believing.

How is it, then, that we may hope to approach still nearer to our ideal—the ideal of a life that finds its purposes completely fulfilled and all conscious experience organized into one perfect whole? Our only course lies in observing what the progress of the world appears to be, and in seeking to develop our lives in harmony with this law of progress. A life that is, thus, in accordance with what we may, perhaps, call the World-Purpose, is a truly moral life, and will thus express the best form of conscious being.

Our only means of discovering in what direction this tendency lies is by a process of trial and error. And this we use whenever we tentatively try a plan of procedure, whenever we experiment with facts and observe their behavior. This process is the role of pure science. If the results of our experiment harmonize with our already organized experience, we accept the modification and apply

the new data to our life, thus producing a corresponding change in our own behavior. This new scheme of conduct we apply again and again to each new episode as it arises, until we find that further revision of our code is, for our individual life, necessary. Thus every process tends to become recurrent and to develop a permanent "set" in the life of the individual. This process of development we find particularly evident in the life of the young conscious being before he has found a plan in life and before he has learned what he ought to do in order to win as much fulfillment of his purpose as it deserves. Mr. Jones.

Now the growth of a self is due purely to its social environment. An adequate model must be provided for purposes of imitation. The deeds of this model the young self will copy, but where it finds that such deeds are not applicable to the development of its own individuality it will interpolate new deeds that may or may not meet the exigencies of the occasion. In this manner a method of procedure will be found that will give some form of expression to the new life. But every such intermediate deed will tend to become recurrent if the result is found to be acceptable, in accordance with what the self hopes to do. Some are satisfied with less, and some require more; so that it becomes quite evident that, if we are to develop high ideals in the young individual, we must give him the widest knowledge possible of what under a great variety of conditions have been the deeds of his fellow men. This he should have before he is allowed to select for himself any particular field of work.

The fundamental defect in our present methods of technical education seems to consist in this, that the tentative period of discovery is entirely ignored. The student is never given breadth of new experience. His life plan becomes recurrent at the outset; and here the writer disagrees with Mr. Swain most heartily; he does not believe that the student should be allowed to select for himself a profession until after a long period of broadening studies. He should not be permitted to look on his education as a mere fount of knowledge which he is to apply to his selected experience of the world. He should be compelled to approach every problem as an experiment, a new source of experience, toward which he is to behave in such a way as his judgment dictates. If his judgment is defective, then his teacher is to aid him in suggesting new processes of conduct, but always leaving to the student the final judgment as to what is right and what is wrong. His model should never be such that he can imitate it deed for deed, but should only suggest to him a course of action between the deeds of the model and his own conscious activities. The importance of thus keeping the young mind in the first or experimental stage as long as possible

Mr. Jones.

must be palpably evident. Each new mode of conduct thus developed is a distinct addition to the ability of the student to adjust himself adequately to the fixed environment of his life. His recurrent stage of being, his permanent mode of behavior toward this environment, should be developed not in response to the demands of the artificial world of his school, but in response to the demands of the actual world in which he is to find his place. This he can find only in so-called practical experience.

Engineering is pretty much the same in any field. It differs only in the sub-classes of facts discriminated. And for this very reason the student should be given a good foundation of general scientific studies, with other selective studies thrown in to add a little zest to his life. After this preparation, which the writer grants, should be begun early in life, the student is able to "choose a profession" with justice both to himself and to the world. This will take time? Of course it will take time—the longer the better, both for the future engineer and for the public, and, of course, the writer is speaking of the majority of engineers.

Of course, it will be readily seen that the engineer is simply an individual who has found his plan in life, and is now applying, recurrently to his experience, the processes he has learned during the more tentative, receptive and progressive period of his being—progressive, because it is very generally during this period alone that opportunity offers itself for original addition to our interpretation of Nature. No man ever wins a purely recurrent form of behavior, because the human consciousness is never able to grasp more than a small fragment of the world at one time. A type of being whose knowledge is so deep that experience comes to it only as facts to which a further application of its present plan of conduct is possible is a super-human self. Some men never attain to a fixed scheme in life, and it is among such men that the idiot is usually to be found. Other men, who have found what kind of activities can best give expression to their life purpose, still retain the power of originating new deeds to a very remarkable degree. To such a class belongs the genius, and in this class belong all those men whose lives have exerted the greatest elevating influence upon the world.

The only measure of the worth of knowledge, then, is whether it broadens and develops the "self." Whether the expression of the "self" requires more or less knowledge for its development is the only criterion of success. The successful life is the life of the man who needs much of the world to express his life purpose, for indeed, the world is no more nor less than the most complete expression that the "self" can gain in the short span of human life.

The fundamental object of education should be to arouse the

student to a perception that it is not the world that limits his life, but that it is his life that limits the world. He should be shown first what relations he and the world bear to one another, and not be urged to swallow as much of the world as he can. Let him, if he can, appreciate the fact that science is never all truth, that the world is not a huge physical laboratory, but that it is shown to us only in terms of conscious purposes seeking their fulfillment, and that the broader, deeper and nobler his purposes, the truer the world will be for him. He may then rest content, if he finds that, in his life, even a small fragment of his chosen work can be completed. He has at least learned what it is to be, and he will know that, however much of his life has been in error, whatever is worthy will find its goal and its fulfillment. For, were there no fulfillments, there could be no purposes to be fulfilled. Mr. Jones.

All this can, and should, be taught as an integral part of the curriculum, not necessarily as a special study—although the writer is convinced that at least a course of lectures could be advantageously added—but indirectly by a modification of the usual methods of instruction due to the employment of men who are teachers, in the real sense, men who, intuitively or otherwise, know enough of the psychology of teaching and the nature of the young mind to make their pupils think, not after any haphazard manner, but logically and reflectively, because they understand and appreciate the nature of the contrast between the world and their ideas.

To the complaint that men of the right caliber say they can find better and more lucrative employment for their abilities in the so-called practical walks of life, answer can be made that an educational system that turns out men so egotistical, so selfish, so dead to the higher duties of life, that they can find it in their hearts to make so dubious an excuse is, *ipso facto,* a bad educational system.

One more word as to the longer period of studies; teachers argue that public opinion is against the six-year course. What if it is? The duty of the teacher is to educate the public up to a point where it will know what is good for it.

# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

OF

# CIVIL ENGINEERS.

(INSTITUTED 1852.)

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VOL. XXXII. No. 8.

OCTOBER, 1906.

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NEW YORK 1906.

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## SOCIETY AFFAIRS.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

**October 3d, 1906.**—The meeting was called to order at 8.40 P. M.; President Frederic P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, 127 members and 21 guests.

The minutes of the meetings of September 5th and 19th, 1906, were approved as printed in the *Proceedings* for September, 1906.

A paper by Augustus Smith, M. Am. Soc. C. E., entitled "The Narragansett Bay Coal Depot" was presented by the author and illustrated with lantern slides. The subject was discussed by E. H. Foster, M. Am. Soc. C. E.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Henry Clarke Ash, Thomson, Minn.
Samuel Givens Bennett, Los Angeles, Cal.
Owen Brainard, New York City.
John Callaghan, Winnipeg, Man., Canada.
Richard Eugene Danforth, Rochester, N. Y.
Frederick Passmore Gutelius, Montreal, Que., Canada.
James Currie Hallock, Paterson, N. J.
Eugene Leonard Harman, St. Louis, Mo.
James Breading Hogg, Uniontown, Pa.
George Leighton, New York City.
Charles Fleming Marsh, London, England.
Walter Scott Morton, Hartford, Conn.
Charles Wellman Parks, Portsmouth, N. H.
John Chester Ralston, San Francisco, Cal.
Ernest Marshall Sprague, Cleveland, Ohio.
Frank Sutton, Washington, D. C.
Andrew Jackson Wenzell, Detroit, Mich.

As Associate Members.

Herbert Mitchell Butterfield, Singapore, Straits Settlements.
Lowell Edwin Conrad, El Oro, Mexico, Mexico.
Ray Howard Corey, Salt Lake City, Utah.
Stanley Cunningham, Jr., New York City.
Charles Tarbell Dudley, San Francisco, Cal.
Frank Edward Frey, Browns Valley, Cal.
William Stewart Harding, Philadelphia, Pa.
Robert Olcott Hayt, Huntley, Mont.
George Hewitt, New York City.
Lester Morton Holt, Hazen, Nev.
Lawrence Milton Lawson, Yuma, Ariz.
Augustine Leftwich Lee, Ambridge, Pa.
Edgar Gleim Maclay, Chicago, Ill.
Tollef Bache Mönniche, Norfolk, Va.
William Madison Myers, Tonila, Jalisco, Mexico.
Clarence Lotario Nelson, Sacramento, Cal.
Paul Leon Price, Pencoyd, Pa.
Clarence J. Rannells, Parkersburg, W. Va.
Dana Watkins Robbins, Albany, N. Y.
George Garnett Shedd, Fall River, Mass.
Elver La Zelle Shinbur, Mitchell, Nebr.

Carl Henry Stengel, Norfolk, Va.
Victor Boureau Sudriers, Montevideo, Uruguay.
David Youngs Swaty, Pittsburg, Pa.
Alberto de la Torre, Bogota, Colombia.
Louis Downer Tracy, Pittsburg, Pa.
Edward Lloyd Walker, New York City.
George Miller Wells, Cristobal, Canal Zone, Panama.

As Associates.

Carlton Eugene Hunt, New York City.
Thomas Burton McIntire, New York City.

The Secretary announced:

The transfer of the following candidates by the Board of Direction, on October 2d, 1906:

From Associate Member to Member.

William Israel Bishop, Montreal, Que., Canada.
Frederic Arnold Kummer, New York City.
Thomas Eugene Leard Lipsey, Beaver, Pa.
Willard Datus Lockwood, Rochester, N. Y.
George Rommel, Jr., Pensacola, Fla.
Ernest Maitland Van Norden, New York City.
Edward Dana Wickes, Kay Moor, W. Va.

From Associate to Associate Member.

Thomas Herbert Letson, New York City.

The election of the following candidates by the Board of Direction:

As Juniors.

On May 1st, 1906:

Richard Elam Mieth, Melville, La.

On June 5th, 1906:

Sheldon King Baker, Corbett, Wyo.

On October 2d, 1906:

Grover Charles Brown, Long Island City, N. Y.
Camden Page Fortney, Coraopolis, Pa.
Everett Burr Hedden, White Plains, N. Y.
Arthur Hirsh Kohn, Boston, Mass.

JAMES ROBINSON MCCLINTOCK, New York City.
FRANCIS BEAL MARSH, Brooklyn, N. Y.
ISAAC SOLON MATLAW, Troy, N. Y.
EDWARD PENDLEBURY, Newark, N. J.
GARFIELD CHRISTIAN PETERSON, Gatun, Canal Zone, Panama.
WILLIAM GUSTAVE ROMMEL, Pensacola, Fla.
WILBOR DICKENS STANTON, Cohocton, N. Y.
VINCENT REYNOLDS STIRLING, Manila, Philippine Islands.

The Secretary announced the following deaths:

JAMES A. BURDEN, elected Member July 2d, 1879; died September 23d, 1906.
JAMES LORING LUSK, elected Member March 4th, 1891; died September 25th, 1906.
FELICIAN SLATAPER, elected Member September 15th, 1869; died September 11th, 1906.

Adjourned.

**October 17th, 1906.**—The meeting was called to order at 8.35 P. M.; President Frederic P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, 104 members and 18 guests.

A paper by Messrs. F. E. Lawrence and P. L. Braunworth, entitled "Fountain Flow of Water in Vertical Pipes," was presented by the Secretary, who also read communications on the paper from Messrs. Edgar C. Thrupp, A. Flamant, and Frank L. Getman.

A paper by Arthur L. Adams, M. Am. Soc. C. E., entitled, "Additional Information on the Durability of Wooden Stave Pipe," was presented by the Secretary, and discussed by Messrs. Shirley Baker and Clemens Herschel.

The Secretary announced the following deaths:

JACOB HAYS LINVILLE, elected Member March 3d, 1875; died August 4th, 1906.

KYOICHI MURAKAMI, elected Member September 4th, 1901; died August 18th, 1906.

Adjourned.

## OF THE BOARD OF DIRECTION.

### (Abstract.)

**October 2d, 1906.**—8.30 P. M.—President Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bissell, Bowman, Gibbs, Knap, Kuichling, Noble, Schneider, Smith, Swensson, and Webster.

The list of names placed in nomination by the Nominating Committee for offices to be filled at the next Annual Election was presented.

Bernard R. Green, Vice-President, Am. Soc. C. E., was appointed a representative of the Society to attend the ceremonies of the opening of the New Engineering Buildings of the University of Pennsylvania, October 19th, 1906.

Applications were considered, and other routine business transacted.

Seven Associate Members were transferred to the grade of Member; one Associate to the grade of Associate Member, and twelve candidates were elected as Juniors.*

Adjourned.

* See pages 355 and 356.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, November 7th, 1906.**—8.30 P. M.—At this regular business meeting, ballots for membership will be canvassed, and a paper entitled "Works for the Purification of the Water Supply of Washington, D. C.," by Allen Hazen and E. D. Hardy, Members, Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for September, 1906.

**Wednesday, November 21st, 1906.**—8.30 P. M.—A paper entitled "Steam Locomotive and Electric Operation for Trunk-Line Traffic—A Comparison of Costs and Earnings," by Joseph Mayer, M. Am. Soc. C. E., will be presented for discussion at this meeting.

This paper was printed in *Proceedings* for September, 1906.

**Wednesday, December 5th, 1906.**—8.30 P. M.—At this regular business meeting, ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "The Atchafalaya River: Some of Its Peculiar Physical Characteristics," by J. A. Ockerson, M. Am. Soc. C. E.; and "The Naval Floating Dock—Its Advantages, Design and Construction," by Leonard M. Cox, M. Am. Soc. C. E.

The paper by Mr. Ockerson was printed in *Proceedings* for September, 1906; Mr. Cox's paper is printed in this number of *Proceedings.*

**Wednesday, December 19th, 1906.**—8.30 P. M.—A paper entitled "Recent Practice in Hydraulic-Fill Dam Construction," by James D. Schuyler, M. Am. Soc. C. E., will be presented for discussion at this meeting.

This paper is printed in this number of *Proceedings.*

**Wednesday, January 2d, 1907.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "The Necaxa Plant of the Mexican Light and Power Company," by F. S. Pearson and F. O. Blackwell, Members, Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

## PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 803 Fulton Building, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner, Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten- Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesbrough, England.

**Civil Engineers' Society of St. Paul,** St. Paul, Minn.

**Koninklijk Instituut van Ingenieurs,** The Hague, The Netherlands.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

## LIST OF NOMINEES FOR THE OFFICES TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 16th, 1907.

The following list of nominees for the offices to be filled at the Annual Meeting, January 16th, 1907, received from the Nominating Committee, was presented to the Board of Direction at its meeting on October 2d, 1906. The list has already been mailed to all Corporate Members.

*For President, to serve one year:*

GEORGE H. BENZENBERG, Milwaukee, Wis.

*For Vice-Presidents, to serve two years:*

JOHN A. BENSEL, New York City.
JOHN A. OCKERSON, St. Louis, Mo.

*For Treasurer, to serve one year:*

JOSEPH M. KNAP, New York City.

*For Directors, to serve three years:*

ALLEN HAZEN, New York City, representing District No. 1.
GEORGE W. TILLSON, Brooklyn, N. Y., representing District No. 1.
FRANK W. HODGDON, Boston, Mass., representing District No. 2.
JAMES CHRISTIE, Philadelphia, Pa., representing District No. 4.
HORACE E. HORTON, Chicago, Ill., representing District No. 5.
ARTHUR L. ADAMS, San Francisco, Cal., representing District No. 7.

# ACCESSIONS TO THE LIBRARY.

From September 10th to October 6th, 1906.

## DONATIONS.*

### SYMMETRICAL MASONRY ARCHES,

Including Natural Stone, Plain Concrete, and Reinforced Concrete Arches. By Malverd A. Howe, M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 10 + 170 pp. New York, John Wiley & Sons, 1906. $2.50.

In the author's previous work, "Treatise on Arches," the general subject of arches has been fully treated. In this book the method of designing masonry arches according to the elastic theory is presented. The preface states that the formulas and methods, as given, are somewhat approximate, the use of rigid formulas not being considered necessary, inasmuch as masonry arches are generally constructed of materials and under conditions which are more or less uncertain in character. The greater part of the book is composed of the solution of examples, each step in a solution being given in detail so as to be easily followed. There is an appendix which contains two tables: Table I gives the physical properties of stone and concrete; and Table II contains general data for more than five hundred masonry arch bridges arranged according to span, and references to periodicals, etc., where more extended descriptions of these bridges can be found. The Contents are: Fundamental Formulas for the Elastic Arch; Symmetrical Arches Fixed at the Ends; Examples Showing the Application of the Formulas, etc.; Typical Arches; Appendix. There is an index of three pages.

### RAILROAD LOCATION, SURVEYS AND ESTIMATES.

By F. Lavis, M. Am. Soc. C. E. Cloth, 9 x 7 in., illus., 7 + 270 pp. New York, The Myron C. Clark Publishing Co., 1906. $3 net. (Donated by the Author.)

The methods given for making railroad locations, surveys and estimates are based on the practice followed on the Choctaw, Oklahoma and Gulf Railroad, now a part of the Rock Island System, on which road the author served as Locating Engineer. The present work was undertaken in order to define these methods and describe, in detail, the actual field practice, particularly the methods of conducting surveys after the general route has been decided; of organizing and handling the party; of obtaining results by short, expeditious methods; of making estimates, etc. These different operations are given in such detail as to be understood as well by the student as by the experienced engineer, and the author hopes that, modified to suit the particular case, they may serve as a precedent for similar work in any kind of country. The Contents are: Résumé of Methods and Explanation of Terms; Reconnaissance, Organization and Equipment; The Preliminary Survey: Field Work; Maps and Office Work; Location; Suburban Rapid Transit Railways; Estimates and Tables of Quantities; Surveys in Tropical Countries and Notes on Modifications of Organization and Equipment; Trigonometrical and Curve Formulas: Tables of Level Cuttings. There are three appendices and an index of four pages.

### WASTE OF WATER IN NEW YORK, AND ITS REDUCTION BY METERS AND INSPECTION:

A Report by James H. Fuertes, M. Am. Soc. C. E., to the Committee on Water-Supply of the Merchants' Association of New York; also a Digest of Laws Governing the Use of Water Meters in New York, by Alfred L. Marilley, and a Summary of Present Conditions Relating to the Water Supply of New York, by J. Hampden Dougherty. Cloth, 10 x 7 in., 272 pp. New York, The Merchants' Association of New York, 1906.

The Contents are: Prefatory: Report of Committee on Water Supply. Waste of Water in New York and its Reduction by Meters and Inspection, by James Fuertes, M. Am. Soc. C. E.: Part I, Methods of Controlling Loss of Water;

*Unless otherwise specified, books in this list have been donated by the publisher.

Part II, The Unaccounted-For Water; Part III, Non-Domestic Use of Water; Part IV, Water Required for Domestic and Public Uses; Part V, Leakage and Wastage; Part VI, On the Amount of Water that may be had from the Croton Water-Shed; Part VII, Future Conditions; Part VIII, Practical Methods of Controlling Leakage and Wastage in New York City; Part IX, The Introduction of Meters in New York as a Business Proposition; Apx. *A*, Unaccounted-For Water; Apx. *B*, Waste of Metered Water; Apx. *C*, Leakage from Street Mains; Apx. *D*, Waste Reduction in American and German Cities: Part I, American Cities; Part II, German Cities: Group I, Cities in Which Waste Reduction has been Accomplished by Metering; Group II, Cities in Which but a Small Proportion of the Supply is Metered; Group III, Cities in Which a Large Proportion of the Supply is Metered; Apx. *E*, List of References. Digest of Laws Governing the Use of Water Meters in New York City, by Alfred L. Marilley: Apx. *A*, Water Rates and Regulations. Summary of Present Conditions Relating to the Water Supply of the City of New York, by J. Hampden Dougherty. There is an index of four pages.

**THE ECONOMICS OF RAILROAD CONSTRUCTION.**

By Walter Loring Webb, M. Am. Soc. C. E. Cloth, 8 x 5 in., illus, 8 + 339 pp. New York, John Wiley & Sons, 1906. $2.50.

It is assumed that those who read or study this book are familiar with the mechanical processes used in railroad surveying and construction, but it is also necessary that an engineer should know something of the economics of railroad construction. This book is written, therefore, from the standpoint of the constructing or operating engineer, to whom is essential a knowledge of the effect of construction on the operation of a road, that is, the operating expenses, locomotive and car construction, train-resistance, and the operation of heavy trains on grades. It also takes up and discusses, from a technical standpoint, the legal methods of railroad organization and finance. Railroad legislation and kindred subjects are considered herein only as they affect questions which must be answered by the railroad engineer. The Contents are: Part I, Financial and Legal Elements of the Problem: Railroad Statistics; the Organization of Railroads; Capitalization; The Valuation of Railway Property; Estimation of Volume of Traffic. Part II, Operating Elements of the Question: Operating Expenses; Motive Power; Economics of Car Construction; Track Economics; Train Resistance; Momentum Grades. Part III, Physical Elements of the Problem: Distance; Curvature; Minor Grades; Ruling Grades; Pusher Grades; Balancing Grades for Unequal Traffic. There is an index of fourteen pages.

## Gifts have also been received from the following:

Aachen, Germany, Kgl. Technische Hochschule. 1 pam.
Alaska Treadwell Gold Min. Co. 2 pam.
Am. Foundrymen's Assoc. 1 pam.
Assoc. of Licensed Automobile Mfrs. 1 pam.
Borini, Joseph. 1 pam.
Boston & Maine R. R. 2 pam.
Buffalo, Rochester & Pittsburgh Ry. Co. 1 pam.
Canada—Dept. of the Interior. 1 bound vol., 2 pam.
Canada—Geol. Survey. 1 bound vol., 1 case of maps.
Canadian Soc. of Civ. Engrs. 1 vol.
Cape of Good Hope—Director of Irrig. 3 pam.
Central Ry. Club. 17 pam.
Chicago & Alton R. R. Co. 1 pam.
Chicago Great Western Ry. Co. 1 pam.
Chicago, Milwaukee & St. Paul Ry. Co. 1 pam.
Chicago, Rock Island & Pacific Ry. Co. 1 pam.
Chicago, St. Paul, Minneapolis & Omaha Ry. Co. 1 pam.
Chicago Terminal Transfer R. R. Co. 1 pam.
Cincinnati, Ohio—Public Library. 1 pam.
Cuerpo de Ingenieros de Minas del Peru. 3 pam.
Eng. Soc. of the School of Practical Sci., Univ. of Toronto. 1 vol.
Eng. Standards Committee. 3 pam.
Fletcher, Robert. 2 pam.
Glasgow & South Western Ry. Co. 1 pam.
Great Britain—Patent Office. 10 vol., 3 pam.
Hocking Valley Ry. Co. 1 pam.
India—Ry. Board. 1 pam.
Inst. of Marine Engrs. 1 bound vol.
Institution of Civ. Engrs. 2 bound vol.
Iowa Univ.—Coll. of Applied Sci. 2 pam.
Iron and Steel Inst. 1 bound vol., 1 pam.
Kanawha & Mich. Ry. Co. 1 pam.
King, G. A. & W. B. 1 pam.
Lake Mohonk Conference on Inter. Arbitration. 1 pam.
Lehigh Valley R. R. Co. 1 pam.
Madras, India—Public Works Dept. 2 pam.
Maine Central R. R. Co. 1 pam.
Mich. Coll. of Mines. 4 pam.
Minneapolis, St. Paul & Sault Ste. Marie Ry. Co. 1 pam.
Miss. River Comm. 1 vol.
Missouri, Kansas & Texas Ry. Co. 1 pam.

Nashville, Chattanooga & St. Louis Ry. 1 pam.
National Assoc. of Cotton Mfrs. 1 bound vol.
National Fire Protection Assoc. 1 pam.
New South Wales—Govt. Statistician. 2 pam.
New York—State Engr. and Surv. 1 vol.
New York City—Board of Water Supply. 1 bound vol.
*New York City Record.* 2 bound vol.
New York, Ontario & Western Ry. Co. 1 pam.
Ohio—State Geol. Survey. 1 bound vol.
Ontario, Can.—Provincial Board of Health. 1 pam.
Platt, T. C. 2 pam.
Reading Co. 1 pam.
St. Francis Levee Board of Arkansas. 1 pam.
Siemens-Schuckert Werke. 2 pam.
Toledo & Ohio Central Ry. Co. 5 pam.
Toledo, Peoria & Western Ry. Co. 1 pam.
Toronto, Ont.—City Engr. 1 bound vol.
United Provinces of Agra and Oudh, India—Public Works Dept. 1 bound vol.
U. S. Bureau of Labor. 1 vol.
U. S. Bureau of Statistics. 5 pam.
U. S. Bureau of the Census. 3 bound vol.
U. S. Forest Service. 4 pam.
U. S. Interstate Commerce Comm. 11 pam.
U. S. Lake Survey Office. 1 pam.
U. S. Library of Congress. 1 bound vol., 1 pam.
U. S. Naval Observatory. 1 bound vol.
U. S. Navy Dept. 1 vol.
U. S. Ordnance Office. 2 pam.
U. S. Reclamation Service. 1 bound vol.
Univ. of Illinois—Eng. Exper. Station. 1 pam.
Western New York Car Service Assoc. 1 pam.
Western Ry. Club. 1 bound vol.
Weston, E. B. 1 pam.

## BY PURCHASE.

**Forscherarbeiten auf dem Gebiete des Eisenbetons, Hefte V-VII.** Berlin, Wilhelm Ernst & Sohn, 1906.

**Repertorium der Technischen Journal-Literatur.** Herausgegeben im Kaiserlichen Patentamt, Jahrgang 1905. Berlin, Carl Heymanns, 1906.

**Notes on Metallurgical Mill Construction.** Edited by W. R. Ingalls. New York, The Engineering and Mining Journal, 1906.

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## SUMMARY OF ACCESSIONS.

From September 10th to October 6th, 1906.

| | |
|---|---|
| Donations (including 12 duplicates) | 164 |
| By purchase | 3 |
| Total | 167 |

## MEMBERSHIP.

### ADDITIONS.

| MEMBERS. | | Date of Membership. |
|---|---|---|
| BRAINARD, OWEN. 28 East 41st St., New York City | | Oct. 3, 1906 |
| HOGG, JAMES BREADING. Civ. and Min. Engr., First National Bank Bldg., Uniontown, Pa | | Oct. 3, 1906 |
| LAVIS, FRED. Res. Engr., P., N. J. & N. Y. R. R., P. O. Station 1, Hoboken, N. J. | Assoc. M. | Sept. 6, 1899 |
| | M. | Sept. 4, 1906 |
| LIPSEY, THOMAS EUGENE LEARD. U. S. Junior Engr., Dam No. 3, Ohio River, Beaver, Pa | Assoc. M. | April 6, 1904 |
| | M. | Oct. 2, 1906 |
| LOCKWOOD, WILLARD DATUS. Res. Engr., Cobbs Hill Reservoir, Rochester, N. Y. | Jun. | April 3, 1894 |
| | Assoc. M. | Oct. 7, 1896 |
| | M. | Oct. 2, 1906 |
| PARKS, CHARLES WELLMAN. Civ. Engr., U. S. N., Navy Yard, Portsmouth, N. H | | Oct. 3, 1906 |
| REED, PAUL LYON. Civ. Engr., U. S. N., Naval Station, Olongapo, Philippine Islands | | July 9, 1906 |
| ROBERTSON, MARSHALL POPE. Mem., State Board of Engrs. of La., 225 Carondelet St., New Orleans, La | Assoc. M. | Mar. 5, 1902 |
| | M. | Sept. 4, 1906 |
| TUCKER, EDWARD AUSTIN. 683 Atlantic Ave., Boston, Mass | | June 6, 1906 |

| ASSOCIATE MEMBERS. | | |
|---|---|---|
| ARMSTRONG, CHARLES JOHNSTONE. Div. Engr., Krugersdorp-Zeerust Ry., Krugersdorp, Transvaal, South Africa | | June 6, 1906 |
| BOYER, CHARLES CARROLL. Kirbyville, Tex | | April 4, 1906 |
| BUSH, PHILIP LEE. Care, Cal. Fruit Canners Assoc., First and Myrtle Sts., Oakland, Cal | | Sept. 5, 1906 |
| DODD, ALBERT BEESTON. Engr., U. S. Reclamation Service, Mitchell, Nebr | | Sept. 5, 1906 |
| GANNETT, FARLEY. Engr. to the Water Supply Comm. of Pennsylvania, 210 North 3d St., Harrisburg, Pa | | April 4, 1906 |
| HARDING, WILLIAM STEWART. Bituminous Coal Operator, Arcade Bldg. (Res., 3411 Hamilton St.), Philadelphia, Pa | Jun. | Nov. 3, 1896 |
| | Assoc. M. | Oct. 3, 1906 |
| NIMMO, JAMES VALENCE. Paspebiac, Que., Canada | | Sept. 5, 1906 |
| WALKER, EDWARD LLOYD. Gen. Insp., Chf. Engr.'s Office, Aqueduct Comm., 280 Broadway. Room 213, New York City | Jun. | Feb. 3, 1903 |
| | Assoc. M. | Oct. 3, 1906 |
| WILSON, JAMES BEAN. Cons. and Contr. Engr., 710 Neave Bldg., Cincinnati, Ohio | | May 2, 1906 |
| WITHERELL, FREDERICK WHITEFIELD. Asst. Engr., Pennsylvania Dept. of Health, Harrisburg, Pa | Jun. | Oct. 6, 1903 |
| | Assoc. M. | July 9, 1906 |

ASSOCIATES.

| | Date of Membership. |
|---|---|
| HAYWARD, HARRISON WASHBURN. Instr., Mass. Inst. Tech., Boston, Mass | June 6, 1906 |
| HUNT, CARLTON EUGENE. Care, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City | Oct. 3, 1906 |

JUNIORS.

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|---|---|
| BAKER, SHELDON KING. Corbett, Wyo | June 5, 1906 |
| BARLOW, JAMES EVANS. 274 Methuen St., Lawrence, Mass | Sept. 4, 1906 |
| BARSHELL, FREDERICK BAYARD. 22 West 114th St., New York City | May 1, 1906 |
| BENNET, ORVILLE GREEN, JR. Care, Eng. Dept., Am. Trading Co., Yokohama, Japan | June 5, 1906 |
| BURTON, WAYNE JOSEPH. P. O. Box 170, Pueblo, Colo | Sept. 4, 1906 |
| CLARK, LE ROY WALTER. Instr., Dept. of Mechanics, Rens. Poly. Inst., 427 Tenth St., Troy, N. Y | Sept. 4, 1906 |
| CLOSSON, EDGAR STONE. 328 Marlborough Rd., Brooklyn, N. Y | Sept. 4, 1906 |
| DOE, CHARLES LEE. 1245 Waverly Pl., Elizabeth, N. J | April 3, 1906 |
| FORTNEY, CAMDEN PAGE. 660 North High St., Morgantown, W. Va | Oct. 2, 1906 |
| GREENE, FRANCIS INGRAHAM. 128 Broad St., Providence, R. I | Sept. 4, 1906 |
| HEDDEN, EVERETT BURR. 30 Orawaupum St., White Plains, N. Y | Oct. 2, 1906 |
| HOHL, LEONARD LOUIS. 1834 Delaware St., Berkeley, Cal | Sept. 4, 1906 |
| JARVIS, CLARENCE SYLVESTER. Care, U. S. Reclamation Service, Huntley, Mont | Sept. 4, 1906 |
| KING, ARTHUR CASWELL. 50 Vernon St., Taunton, Mass. | Sept. 4, 1906 |
| KOHN, ARTHUR HIRSH. Jamaica Plains, Boston, Mass | Oct. 2, 1906 |
| LINDSAY, RICHARD LEE. 202 Empire Bldg., Atlanta, Ga. | Sept. 4, 1906 |
| MARSH, FRANCIS BEAL. 1456 Fifty-second St., Brooklyn, N. Y | Oct. 2, 1906 |
| MATLAW, ISAAC SOLON. 210 Eighth St., Troy, N. Y | Oct. 2, 1906 |
| MIETH, RICHARD ELAM. Melville, La | May 1, 1906 |
| RACKLE, OSCAR WILLIAM. 23 Caswell Hall, Brown Univ., Providence, R. I | Sept. 4, 1906 |
| SYKES, GEORGE. Care, New York Edison Co., 55 Duane St., New York City | May 1, 1906 |
| THOMPSON, JAMES LOYD. Care, U. S. Reclamation Service, Corbett, Wyo | Sept. 4, 1906 |
| TIBBETTS, FREDERICK HORACE. Univ. of California, Berkeley, Cal | May 1, 1906 |
| TIRRELL, CHARLES EDWARDS. So. Weymouth, Mass | Sept. 4, 1906 |

## DEATHS.

BURDEN, JAMES ABERCROMBIE. Elected Member, July 2d, 1879; died September 23d, 1906.

LINVILLE, JACOB HAYS. Elected Member, March 3d, 1875; died August 4th, 1906.

LUSK, JAMES LORING. Elected Member, March 4th, 1891; died September 25th, 1906.

SLATAPER, FELICIAN. Elected Member, September 15th, 1869; died September 11th, 1906.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(September 10th to October 6th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles, references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month, 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeischrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Building, Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.

## LIST OF ARTICLES.

### Bridge.

The Bout de l'Isle Bridge.* J. L. Morris, M. Can. Soc. C. E. (5) Jan.
Moving Loads on Railway Under-Bridges.* H. Bamford. (11) Serial beginning Sept. 7.
Maximum Bridge Stresses Under Live Load. R. M. Packard. (14) Sept. 8.
Steel Falsework Used in the Erection of the Quebec Bridge.* (14) Sept. 8.
The Caneadea Viaduct of the Buffalo & Susquehanna Ry.* Joseph Mayer, M. Am. Soc. C. E. (13) Sept. 13.
Equivalent Uniform Live Loads for Railroad Bridge Trusses.* J. E. Kirkham, Assoc. M. Am. Soc. C. E. (13) Sept. 13.
The Transporter Bridge at Newport (Monmouthshire).* (12) Sept. 14.
Strauss Ribbed Concrete-Steel Bridge for the Elgin-Belvidere Electric Railroad.* (15) Sept. 14.
The Newport Electric Bridge Transporter.* (73) Sept. 14.
Bridges for Electric Railways.* C. C. Schneider. (17) Serial beginning Sept. 15.
Camber Adjustments Made in the Erection of the Quebec Bridge.* (14) Sept. 15; (46) Sept. 29.
An Eight-Track Reinforced-Concrete Viaduct in Winnipeg, Manitoba.* (14) Sept. 15.
Progress on the Blackwell's Island Bridge.* (14) Sept. 15.
Raising of Canal Bridge at Schenectady, New York.* (15) Sept. 21.
A Three-Hinged Concrete Arch Bridge.* (14) Sept. 22.
A Four-Span Reinforced Concrete Arch Bridge on the Southern Railway.* H. C. Harrison. (14) Sept. 22.
The Syratal Viaduct in Plauen, Bohemia.* E. Ommelange. (15) Sept. 28.
The Long Lake Highway Bridge.* (14) Sept. 29.
Déplacement de la Passerelle de Passy.* L. Biette. (43) Pt. 2.
Pont-route Au-dessus de la Gare de Muysen (Belgique).* Léon Cosyn. (35) Sept.
Belastungsversuche mit Visintiniträgern für Gleisüberführung in Dänemark.* Sophus M. Andersen. (78) Aug.
Ein Neues Verfahren zur Graphischen Bestimmung der Stabkräfte in Fachwerkslaufkranbrücken.* A. Baumann. (82) Serial beginning Sept. 1.

### Electrical.

Measurement of Electrical Conductivity of Short Rods.* Rollo Appleyard, Assoc. M. Inst. C. E. (63) Vol. 164.
The Effect of Load Factor on Cost of Power.* E. M. Archibald. (5) Jan.
Interference in Wireless Telegraphy.* John Stone Stone. (5) Jan.

*Illustrated.

**Electrical—(Continued).**

An Investigation of a 16 K. W. Constant Current Transformer.* C. H. Wright. (5) Jan.
Long Flame Arc Lamps.* Leonard Andrews. (77) Aug.
Waste in Incandescent Electric Lighting and Some Suggested Remedies.* Geo. Wilkinson. (77) Aug.
"Idle Currents." M. B. Field. (77) Aug.
The Distribution of Magnetic Induction and Hysteresis Loss in Armatures.* W. M. Thornton. (77) Aug.
An Investigation into the Periodic Variations in the Magnetic Field of a Three-Phase Generator by Means of the Oscillograph.* Gladstone W. Worrall and Thos. F. Wall. (77) Aug.
On the Electric Inductive Capacities of Dry Paper and of Solid Cellulose.* Albert Campbell. (Paper read before the Royal Soc.) (73) Serial beginning Aug. 31.
The Value and Effect of High-Efficiency Incandescent Lamps.* F. W. Willcox. (Abstract of paper read before the National Elec. Light Assoc.) (73) Serial beginning Aug. 31.
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The Sudden Short-Circuiting of Alternators.* F. Punga. (73) Aug. 31.
The Electrical Discharge in Air and its Commercial Application.* William Cramp and Sidney Leetham. (Paper read before the Brit. Assoc. for the Advancement of Science.) (73) Aug. 31.
The Effect of Iron in Distorting Alternating-Current Wave Form.* Frederick Bedell and Elbert B. Tuttle. (42) Sept.
On the Experimental Determination of the Ratio of the Electrical Units.* Lord Rayleigh. (From the *Phil. Mag.*) (73) Serial beginning Sept. 7.
The Transfer of the Hop National Telephone Exchange from Magneto to Common Battery Working.* G. F. Greenham. (26) Sept. 7.
Accurate Speed, Frequency and Acceleration Measurements.* Charles V. Drysdale. (26) Serial beginning Sept. 7.
On the Rapid Calculation of Field Coil Windings.* Geo. T. Hanchett. (27) Sept. 8.
The Cadmium Standard Cell. George A. Hulett. (From the *Physical Review.*) (73) Serial beginning Sept. 14.
Power Transmission Lines.* T. L. Kolkin. (70) Serial beginning Sept. 14.
High-Speed Electric Machinery with Special Reference to Steam-Turbine Machines.* Silvanus P. Thompson. (29) Serial beginning Sept. 14.
Self-Exciting, Low-Frequency Alternator.* G. Faccioli. (27) Sept. 15.
The New Hydro-Electric Station of the Holyoke Water Power Co.* (14) Serial beginning Sept. 15.
Electric Passenger-Lifts for the Baker Street and Waterloo Railway.* (11) Sept. 21.
Oscillographs and Some of Their Recent Applications.* David A. Ramsey. (73) Sept. 21.
Modern Forms of Electric Incandescent Lamps. C. R. Böhm. (Abstract from the *Elektrotechnischer Anzeiger.*) (73) Sept. 21.
Characteristic Performance of Polyphase Magnets.* D. L. Lindquist. (27) Sept. 22.
The Newton-Boston Edison Sub-station.* (27) Sept. 29.
The Design and Construction of a 100-Mile Wireless Telegraph Set.* A. Frederick Collins. (19) Oct. 6.

**Marine.**

Note on the Towing-Resistance of a Floating Dock.* Henry Aylwin Bevan Cole, M. Inst. C. E. (63) Vol. 164.
The Construction of a Timber Dry Dock.* G. B. Ashcroft, A. M. Can. Soc. C. E. (5) Jan.
Armour and Its Attack.* W. E. Edwards. (Paper read before the British Assoc.) (12) Sept. 7.
Oil Extraction.* A. B. Willets. (20) Sept. 13.
The Cunard Steamship *Mauretania*, the Largest Vessel Ever Built.* (13) Sept. 27; (11) Sept. 14; (12) Sept. 21.
An Application of Stream-Line Apparatus to Determine the Direction and Approximate Magnitudes of the Principal Stresses in Certain Parts of Ships.* (Paper read before the British Assoc.) (11) Sept. 28.
Der Belgische Turbinen-Postdampfer *Princesse Elisabeth.** (48) Serial beginning Sept. 8.

**Mechanical.**

Compression of Steel Ingots in the Mould.* A. J. Capron. (71) Vol. 69.
Chain-Making Machinery.* Emile Lelong. (71) Vol. 69.
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Gas as a Motive Power, and its Relative Cost.* W. H. Laurie, M. Can. Soc. C. E. (5) Jan.
Regulation of the Duration of Combustion.* Byron Eldred, M. Am. Soc. M. E. (3) Sept.
The Planning and Construction of the Power Plant.* A. E. Dixon. (9) Sept.
The Mechanical Uses of Water Under Pressure.* Wm. M. Barr. (9) Sept.
Machinery and Processes in a Modern Portland-Cement Plant.* F. H. Lewis. (9) Sept.
The Comparative Cost of Steam Engines, Steam Turbines, and Gas Engines for Works Driving.* W. Schömburg. (Abstract from *Elektrotechnische Zeitschrift.*) (26) Sept. 7.
Difficulties in Converting Gasoline Engines to Operate on Producer Gas. J. E. Pfeffer. (62) Sept. 8.
Buckeye Gas Engine.* (18) Sept. 8.
Power Plant of the Hotel St. Regis, New York.* (14) Sept. 8.
New Serious Competitors of Electric Motor Cars.* (27) Sept. 8.
Modern Pipe Founding. H. A. Croxton. (Abstract of paper read before the Amer. Foundrymen's Assoc.) (47) Sept. 8.
Working Drawings of a 7 B. H. P. Gas Engine. (47) Serial beginning Sept. 8.
Balanced Draft Gas Producer Furnace as Applied to Steam Boilers.* Embury M'Lean. (Abstract of paper read before the Brooklyn Engrs. Club.) (20) Sept. 13; (64) Aug.
Methods of Burning Small Anthracite Coal. E. H. Peabody. (14) Sept. 15.
A Novel Cableway System of Coal Storage.* (14) Sept. 15.
Simple Methods of Gas Analysis. S. J. B. Tully. (Paper read before the Irish Assoc. of Gas Mgrs.) (24) Sept. 17.
A Comparison of Horizontal, Inclined and Vertical Retorts. (Tr. from paper contributed in competition for the Italian Gas Society's international prizes.) (66) Sept. 18.
Kramers and Aarts Water-Gas Plant and its Use in Gas-Works.* A. Steger. (Paper read before the Soc. Tech. du Gaz en France.) (66) Serial beginning Sept. 18.
140-Ton Floating Crane.* (12) Sept. 21.
Mechanical Plant of the First National Bank Building, Chicago.* (14) Serial beginning Sept. 22.
The Engineering and Machinery Exhibition, Olympia.* Joseph Horner. (11) Sept. 28.
Fuel Analysis for Steam Users.* John B. C. Kershaw. (12) Serial beginning Sept. 28.
Engine Breakdowns and Their Lessons.* Michael Longridge, M. Inst. C. E. (Abstract of Report of the Chief Engr. of the Brit. Engine, Boiler and Elec. Insurance Co., Ltd.) (47) Serial beginning Sept. 29.
Centrifugal Pumps.* P. A. Mossay and G. M. Brown. (Abstract of paper read before the Rugby Eng. Soc.) (47) Serial beginning Sept. 29.
The Power Plant of the Pittsburg Terminal Warehouse and Transfer Co.* (14) Sept. 29.
How Horizonal Runs Affect the Air Lift. Herbert T. Adams, M. Am. Soc. M. E. (60) Oct.
Fuels and Combustion. Sanford A. Moss. (64) Serial beginning Oct.
Setting the Valves of the Fleming Four-Valve Engine.* Thomas Hall. (64) Oct.
The Preservation of Surface Condenser Tubes in Plants Using Salt or Contaminated Water Circulation. W. W. Churchill. (Paper read before the Amer. Assoc. for the Advancement of Science.) (64) Oct.
Some Notes on Steam Boiler Troubles.* Horace See. (Paper read before the Soc. of Naval Archts. and Marine Engrs.) (64) Oct.
Reciprocating Steam Engines *vs.* Steam Turbines; a Comparison of Operation Between Two Power Houses of Modern Type. W. P. Hancock. (10) Oct.
The Removal of Napthaline from Coal Gas.* Alfred H. White and Joel M. Barnes. (Paper read before the Michigan Gas Assoc.) (24) Oct. 1.
Claims of Coke Ovens to a Place Among Gas Works. F. C. Moon. (From the *Gas World.*) (83) Oct. 1.
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The Scullin-Gallagher Iron and Steel Company; Important Additions to the Steel Casting Plant.* (20) Oct. 4.
Lignite Briquets.* Elwyn Waller and H. Stanley Renaud. (16) Oct. 6.
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Der Ausfluss von heissem Wasser.* Julius Adam. (48) Serial beginning July 21.
Untersuchungen an Drucklufthämmern.* P. Möller. (48) July 21.
Antrieb von Drehbänken mittels Fünfstufiger Wirtel. W. Hansen. (48) July 21.
Ueber Dampfturbinen. A. Riedler. (48) Serial beginning Aug. 4.

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Der Zusammenhang von Konstruktion und Fabrikation Americanischer Werkstätten.* Schmerse. (48) Aug. 11.
Der Dampfturbinenbau der Allgemeinen Elektricitäts-Gesellschaft, Berlin.* O. Lasche. (48) Serial beginning Aug. 18.
Neuerungen im Amerikanischen Transportmaschinenbau.* Georg von Hanffstengel. (48) Serial beginning Aug. 25.
Die Bestimmung der Wirtschaftlichsten Dampfanlage für Betriebe mit Bedarf an Heizdämpfen. G. Marzahn. (82) Serial beginning Aug. 25.
Die Mastenkrananlage der Berlin-Anhaltischen Maschinenbau—A. —G. in Berlin.* K. Specht. (48) Sept. 8.
Die Kraftmaschinen auf der Deutschböhmischen Ausstellung in Reichenberg.* K. Körner. (48) Serial beginning Sept. 15.
Mitteilungen über Dampfturbinen.* A. Rateau. (48) Serial beginning Sept. 15.

**Metallurgical.**

Brittleness and Blisters in Thin Steel Sheets.* Edward F. Law. (71) Vol. 69.
The Effect of Copper in Steel. F. H. Wigham. (71) Vol. 69.
The Early Use of Iron. Bennett H. Brough. (71) Vol. 69.
Volume and Temperature Changes During the Cooling of Cast Iron.* Thomas Turner. (71) Vol. 69.
Influence of Silicon, Phosphorus, Manganese, and Aluminium on Chill in Cast Iron.* E. Adamson. (71) Vol. 69.
Preliminary Note on the Influence of Manganese on Iron. J. O. Arnold and F. K. Knowles. (71) Vol. 69.
Use of Oxygen in Removing Blast-Furnace Obstructions. C. de Schwarz. (71) Vol. 69.
The Electro-Thermic Production of Iron and Steel.* Eugene Haanel. (5) Jan.
The Manufacture of Steel in Open-Hearth Furnaces.* Horace Allen. (From *The Brass World.*) (47) Sept. 1.
Recovery Coke-Ovens.* (66) Sept. 4.
The Annealing of Non-Ferrous Metals.* (22) Sept. 7.
The Electro-Thermal Metallurgy of Iron.* E. Stassano. (Paper read before the Congress of Applied Chemistry.) (73) Sept. 7.
Beehive Oven Construction in the Connellsville and Pocahontas Coking Regions.* Howard N. Eavenson. (From the *Transactions* of the Appalachian Eng. Assoc.) (22) Sept. 28; (57) Sept. 28.
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**Military.**

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Electric Machinery for the Operation of Mexican Mines.* Charles V. Allen. (9) Serial beginning Sept.
Steam Consumption of a Modern Hoisting Plant.* S. Powell, Jr. (16) Sept. 15.
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The Savage River Pumping Plant.* L. B. Abbott. (16) Sept. 29.
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Drifting and Stoping at Lake Superior.* W. R. Crane. (16) Oct. 6.
Ersatz des Holzausbaues in Wilhelmschacht II. des Königlichen Steinkohlenbergwerkes König (Saarrevier) durch Eisen-Beton.* Hundt. (78) Aug.
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**Miscellaneous.**

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Application de la Méthode des Points Alignés au Tracé des Paraboles de Degré Quelconque.* Farid-Boulad. (43) Pt. 2.

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Dust Prevention Experiments in Surrey. Frank G. Howell. (Abstract of report to the County Council, Surrey, England.) (60) Oct.

**Railroad.**

A Simplified Method of Laying Out Transition-Curves.* Thomas Alexander Ross, Assoc. M. Inst. C. E. (63) Vol. 164.
Fracture of Axles Originating in Drilled Holes.* Lucien Alphonse Legros, Assoc. M. Inst. C. E. (63) Vol. 164.
The Railway-Gauges of India.* Sir Frederick Robert Upcott, M. Inst. C. E. (63) Vol. 164.
The Economical Working of Locomotives.* William Ernest Dalby, M. Inst. C. E. (63) Vol. 164.
The New Inclines of the São Paulo Railway, Brazil. James Fforde, M. Inst. C. E. (63) Vol. 164.
Solid Rolled Steel Car Wheels and Tires.* Peter Eyermann. (71) Vol. 69.
The Proportions and Design of Locomotive Crossheads.* W. F. Drysdale. (5) Jan.
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Determination of the Degree of Fragility and of Homogeneity of Rail-Steel by Impact-Test with Notched Bars.* S. Drouginine. (Abstract of paper read before the International Assoc. for Testing Materials.) (18) Sept. 15.
Frogs and Crossings. S. Uren. (Abstract of paper read before the International R. R. Master Blacksmiths' Assoc.) (18) Sept. 15.

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The New Terminal Station and Ferryhouse of the Delaware, Lackawanna & Western R. R. at Hoboken, N. J.* Charles C. Hurlbut. (13) Sept. 20.
The Walschært Valve Gear. O. H. Rehmeyer. (Report presented to the Traveling Engrs. Assoc.) (13) Sept. 20.
Track Construction for Railway Tunnels.* (13) Sept. 20.
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Varnish. J. H. Pitard. (Abstract of paper read before the Master Car and Locomotive Painters' Convention.) (40) Sept. 21.
Vauclain Balanced Compound Locomotive for the Chicago and Eastern Illinois Railroad.* (11) Sept. 21.
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Large Electric and Steam Locomotives. J. E. Muhlfeld. (Paper read before the N. Y. R. R. Club.) (19) Serial beginning Sept. 22.
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Les Voies d'Accès au Simplon.* Jean Brunhes. (Abstract from *Revue Economique Internationale.*) (38) Sept.
Wagons-Trémies de 20 Tonnes à Déchargement Automatique, Système Malissard-Taza.* (33) Sept. 15.
Le Desserrage des Vis dans les Assemblages Métalliques des Voies de Chemins de Fer.* L. Schlüssel. (33) Sept. 22.
Eisenbetonpfähle und Ihre Anwendung für die Gründungen im Neuen Bahnhof in Metz.* H. Schürch. (51) Serial beginning July 21; (80) Sept. 6.
Der Eisenbetonbau bei den Neuen, durch die K. K. Eisenbahnbau-direktion hergestellten Bahnlinien der Oesterreichischen Monarchie.* August Nowak. (78) Serial beginning Aug.
Das Leistungsgebiet der Dampflokomotive. R. Sanzin. (53) Serial beginning Aug. 3.
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Advantages and Disadvantages of Different Systems of Tramway Brakes.* Scholtes and Bjorkegren. (Reports to the Union Internationale de Tramways et de Chemins de Fer d'Intérêt Local.) (73) Sept. 7.
Importance of Effective Brush-Holder Inspection.* Henry Schlegel. (17) Sept. 8.
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Car Brakes. Henry Mozley. (Abstract of paper read before the Mun. Tramways Assoc.) (26) Sept. 21; (73) Sept. 21.

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Standardization of Direct-Current Traction Motors. (Report to the Milan Convention.) (17) Sept. 22.
Brake Systems for Electric Railways. Scholtes. (Report to the Milan Convention.) (17) Sept. 22.
Track Construction in City Streets.* Dubs. (Abstract of paper read before the Milan Convention.) (17) Sept. 22.
Wattmeters and Other Current Recorders for Cars. Wattmann. (Abstract of paper read before the Milan Convention.) (17) Sept. 22.
Continuous *vs.* Sectionalized Overhead Systems.* G. Rasch. (Paper read before the Milan Convention.) (17) Sept. 22.
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Grid Starting Coils.* Henry Schlegel. (17) Oct. 6.
Die Erweiterung der Berliner Untergrundbahn nach dem Westen.* (51) Serial beginning Aug. 11.

**Sanitary.**

The Elimination of Storm-Water from Sewerage Systems.* David Ernest Lloyd-Davies, Assoc. M. Inst. C. E. (63) Vol. 164.
On the Elimination of Suspended Solids and Colloidal Matter from Sewage.* Alfred Stowell Jones, M. Inst. C. E., and William Owen Travis. (63) Vol. 164.
The Elimination of Redundant Parts in the Forced Circulation of Hot Water.* A. H. Barker. (Paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (70) Sept.
Notes on the Use of Feed-Water Heaters in Connection with Heating Systems.* William G. Snow. (Paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (70) Sept.
Gas for Heating Boilers and House Furnaces. Robert Munro. (Paper read before the Natural Gas Assoc. of America.) (83) Sept. 15.
The Life-History for Eight Years of the Experimental Coke Clinker Filter-Beds at Kingston-on-Thames. Douglas Archibald. (Abstract of paper read before the Royal Sanitary Inst.) (14) Sept. 22.
The Sewerage of Baltimore.* Calvin W. Hendrick. (60) Oct.
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Die Beseitigung von Hausmüll. Klemens Dorr. (53) Serial beginning Aug. 17.
Die Entwässerungsanlagen der Stadt Dresden und Ihre Ausbildung für die Zwecke der Schwemmkanalisation.* Klette. (51) Serial beginning Aug. 18.

**Structural.**

"The Relation Between Type of Fracture and Micro-Structure of Steel Test-Pieces." C. O. Bannister. (71) Vol. 69.
Fires and Their Prevention in Factories.* F. B. Sanborn. (Paper read before the Boston Soc. of Civ. Engrs.) (1) July.
Coal-Tar Paint. A. C. Cunningham. (Abstract from *Journal* of the Amer. Soc. of Naval Engrs.) (66) Sept. 4.
A 40-Story Building in New York City.* (14) Sept. 8.
Test of the Effect of Heat on Reinforced Concrete Columns.* H. B. MacFarland. (13) Sept. 20; (14) Sept. 22.
Tests of Reinforced Concrete Beams.* C. J. Tilden, Assoc. M. Am. Soc. C. E. (Paper read before the Amer. Soc. for Testing Materials.) (18) Sept. 22.
Influence of Tamping on the Strength of Concrete.* H. Burchartz. (14) Sept. 22.
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Methods of Testing Metals by Alternate Strains, and Thermic Treatment of Steels to Increase Their Resistance. James E. Howard. (Abstract of Discussion read before Inter. Assoc. for Testing Materials.) (14) Sept. 22.
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A Reinforced Concrete Tunnel Caisson.* (14) Serial beginning Sept. 29.
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Strength Properties of Brickwork as Determined by Experiment. W. C. Popplewell. (Abstract of paper read before the Brit. Inst. of Sanitary Engrs.) (60) Oct.
Compte Rendu du Congrès Francais de la Prévention du Feu dans les Batiments, tenu à Paris du 1er au 5 Mars, 1906; Résumé Analytique des Travaux. Henri Favrel. (32) June.
Villa à Fontenay-aux-Roses (Seine), M. L. Muret, Architecte.* E. Rivoalen. (35) Sept.
Die Abhängigkeit der Bruchlast vom Verbunde und die mittel zur Erhöhung der Tragfähigkeit von Balken aus Eisenbeton.* Fritz v. Emperger. (79) Vol. 5.

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Beitrag zur Vereinfachung der Berechnung von Eisenbetonkonstruktionen.* Jopke. (78) July.
Bestimmung der Löslichen Kieselsäure in Kalksandsteinen. M. Glasenapp. (80) July 26.
Zur Dimensionirung der Beiderseits Armierten Balken. Siegfr. Carl Drach. (78) Aug.
Massivplatten mit Kreuzweiser Eisenarmierung. H. Froelich. (78) Aug.
Träger mit Kleinster Durchbiegung; Träger mit Kleinstem Biegungswinkel am Ende. Gustav Kull. (82) Aug. 4.
Einfluss von Ton auf die Festigkeit von Beton. H. Seger and E. Cramer. (From the Chemischen Laboratorium für Tonindustrie.) (80) Aug. 18.
Ein Fall des Eingespannten, auf Zug und Biegung beanspruchten Stabes. Ivan Arnovlevic. (53) Aug. 24.
Der Eisenbeton-Kuppelaufbau des Armee-Museums in München. Zöllner. (51) Serial beginning Aug. 29.
Das Berechnen Einer Verblendziegelfassade.* Gust. Benfey. (80) Sept. 11.

**Topographical.**

The Northern Boundary of Massachusetts. Nelson Spofford. (Paper read before the Boston Soc. of Civ. Engrs.) (1) July.

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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

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# PAPERS AND DISCUSSIONS.

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## THE NAVAL FLOATING DOCK— ITS ADVANTAGES, DESIGN AND CONSTRUCTION.

By Leonard M. Cox, M. Am. Soc. C. E.

To be Presented December 5th, 1906.

A nation's foreign commerce is a measure of its wealth. Foreign commerce is carried on by means of ships; and ships require harbor and docking facilities. Other conditions being equal, that port offering the best facilities for cleaning and repair work, in addition to deep water and protected berthing, will reap the largest measure of prosperity. The speed of a ship, for a given coal consumption, is a factor of its earning capacity, and marine growths foul a ship's bottom, affecting thereby its speed. Iron and steel corrode in salt water, and must be given protective coverings; these coverings last but a short time in active service, and require periodical renewals. Ships are likely to be damaged by grounding or by collisions, and access to their bottoms must be provided, in order to make the necessary repairs. In fact, from the very beginning of sea commerce, the question of repair docks has been of vital interest to merchants and ship owners as well as to governments, and, in view of the great movement toward commercial expansion, which has marked the last

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

decade, it is safe to assume that this interest will at least continue, and that a discussion of the subject will not fail to be of interest to an engineering society.

Historically, three epochs in ship-repairing appliances are marked: By the use of tide flats, when the Phœnicians careened their vessels on the shores of the Mediterranean; by the crude mud docks of the Greeks; and, by the (legendary) use by the North Country captain, of the hulk *Camel* as the forerunner of the floating dock. From these crude prototypes, the evolution of our modern structures followed. Increased demand and more exacting requirements have brought about improvements of design and of methods of operating; but, as regards general type and working principles, very little that is really new can be claimed.

Repair docks may be considered under four heads: The Graving Dock; the Floating Dock; the Marine Railway; and the Lift Dock.

*The Graving Dock or Dry Dock.*—The graving dock is an excavation in the foreshore of a harbor, cut off from the basin by portable gates or caissons. It may be lined with timber, stone, concrete, or combinations of these materials. After the ship is floated into the dock and centered over the blocking, the gates are closed, and the water is removed by pumps.

*The Floating Dock.*—The floating dock is a hollow structure, of wood, iron or steel, capable of being submerged by the simple admission of water to its interior, and of being raised to its lightest flotation again by means of pumps. When the dock is submerged, the ship is floated into position, the pumps are started, and the dock, with the ship on its deck, is raised until the ship's bottom is out of the water.

*The Marine Railway.*—The marine railway consists of inclined ways extending for some distance under the water. The ship is received on a cradle and hauled up on the shore.

*Lift Docks.*—Lift docks include those devices which consist essentially of a platform, capable of being raised and lowered by hydraulic or other power.

The limits of this paper confine consideration to the floating dock proper, but no discussion of one particular type of dock would be complete without some attempt to set forth the considerations governing the choice of types.

One of the results of many investigations prosecuted by intending builders is the apparent division of engineers and naval architects into dry dock and floating dock adherents. It is evident, however, that each type has its own particular field of usefulness which the other cannot with advantage fill, and that, for a given set of conditions, a careful study of both types, as applied to the special requirements of the case, must govern the choice.

For commercial purposes, the advantages of the stationary or basin dry dock consist in the fact that it can be used in shallow harbors, and that the ship, when seated, is safe. Its disadvantages lie in its greater first cost (except in the case of timber docks in favorable foundations); the greater quantity of water to be pumped; the lack of good ventilation and proper light under the ship's bottom; and the area of land required. The floating dock has the advantage of smaller first cost; no land space required; the ability to maintain the ship in virtually the same shape as when waterborne; and finally, its mobility. Its disadvantages are the possibility of accident (the chances of which, however remote, can never be entirely eliminated); the necessary occupation of useful water front; and the greater depth of water required for operation.

From the standpoint of naval requirements, the case is different. Sir William H. White, Hon. M. Am. Soc. C. E., in the discussion on dry docks,* at the International Engineering Congress, at St. Louis, in 1905, says:

"A modern ship, especially a modern warship, obviously requires careful handling in docking. An armored ship with hundreds of tons of armor on her sides, and of great width, is built with a bottom that is comparatively an egg-shell, and, unless properly supported, there are enormous risks in docking such a structure. It is quite easy to crush up the bottom of such a ship unless great care is taken. The case of the U. S. Cruiser, *Columbia*, when docked at Southampton, is well known. The spacing of the blocks was just such as would have been practiced with ordinary merchant ships, but it was not suitable to the light structure of the warship and the results were anything but satisfactory. The speaker has been in the double bottom of a large ironclad docked in a Government dockyard in England, where, owing to want of care, certain portions of the structure were pushed up in relation to others, and the light framework at the bottom was squeezed in a very uncomfortable manner."

* *Transactions*, Am. Soc. C. E., Vol. LIV, Part F.

The modern warship has a delicate framework, of small local resistance, and, as it represents an outlay of several millions of dollars, the question of subjecting it to any sort of risk is one which calls for serious consideration. For docking ships of this character, the consensus of engineering opinion seems to favor the basin dock, because of its safety, its rigidity, and the smaller liability of error from the personal equations of operators. One of the objects of this paper is to show just how far the latest practice in floating dock construction has gone toward minimizing, or even eliminating, these objections, while developing the peculiar advantages of the type.

*First Cost of Docks.*—Ten years ago, or more, the timber dry dock was much favored in America on account of its small first cost and the short time required for construction. As far as naval purposes are concerned, however, the question of material for docks appears to have been settled in favor of masonry, since experience with timber docks established the fact that they were temporary structures at best, and that the small first cost was more than offset by the large charges against maintenance. As compared with the timber dry dock, the first cost of the floating dock is greater; but, as compared with the cost of the modern masonry dock capable of docking the same ships—and the policy of the Navy Department for the last ten years has been in favor of masonry docks—the floating dock costs about the same and in some instances less.

The first cost of masonry dry docks depends to a great extent upon the nature of the foundation encountered, and the necessary uncertainty of this factor often renders it impossible to prepare accurate preliminary estimates. The cost of a dry dock varies according to different localities, labor conditions, and prices of materials; and, in consequence, it is impossible to make a general comparison of cost between the floating and the stationary structures. Whenever such comparison is attempted, however, docks of essentially the same capacity should be selected. To arrive at an equitable comparative rating, regard must be had for the lifting capacity, the clear width of entrance, the available length, and the maximum draft of water over the blocks. A dry dock will support the heaviest ship than can be placed in its basin, while a floating dock will lift only the load for which it is designed. A floating dock has an avail-

able depth of water equal to the height of the side walls less the height of the keel blocks, plus the required freeboard, while the depth of a dry dock is fixed by the depth of water over the sill. A floating dock can lift a ship whose keel length does not exceed the length of the blocking, whereas the capacity of a dry dock is limited by its own length. As regards clear breadth between walls, that dimension is usually the same throughout the length of the floating dock, while in dry docks the width at entrance must govern. In making comparisons, the lifting capacity of the floating dock may be disregarded, as its dimensions usually govern a ship's weight, and a dock of a certain lifting capacity would rarely be designed with such dimensions as would admit a ship of excessive weight.

The most important particular, however, is the matter of breadth. At present, the largest and heaviest battleships are of the new 16 000-ton type, 450 ft. in length, 76 ft. 10 in. in breadth and having a mean draft of 24 ft. 6 in. That the limit in size has not yet been reached is evident from the fact that even now tentative plans for 18 000-ton ships are being proposed, while even 20 000-ton ships have been advocated. It is reasonable, perhaps, to suppose that such increase in size will be accompanied by some increase of beam, and it is interesting to note that of the American naval dry docks now constructed, only four could take ships of these dimensions, and, of these four, those at Portsmouth and Boston have only recently been completed, while Dock No. 3 at the New York Navy Yard and the Puget Sound Navy Yard dock afford such narrow margin between the entrance walls and the ship that it is doubtful if constructors would care to undertake the risk involved in docking. When those now being constructed are completed, five docks, amply large for such ships and with a fair margin for future expansion, will be added to this list. On the whole, then, it is here proposed that, in comparisons of the cost of the two types, the floating dock be regarded as equivalent to a dry dock having a width at entrance the same as the clear width between its side walls, having a length exceeding its own by at least 100 ft., and having a maximum depth of water over the keel blocks equal to the maximum depth attainable in the floating dock. On this basis the dock, *Dewey*, for instance, could be compared with Dock No. 3 at the Norfolk Yard, Dock No. 1 at Charleston (both under construction), and with the new Boston

and Portsmouth docks. Table 1 gives the first cost of the naval docks of the United States.

TABLE 1.—FIRST COST OF UNITED STATES NAVAL DRY DOCKS.

BASIN DOCKS.

| Location. | Material. | Date of Completion. | Original cost. | Remarks. |
|---|---|---|---|---|
| Boston, No. 1..... | Masonry. | 1833 | 972 717.29 | |
| Boston, No. 2..... | Masonry. | 1905 | 1 105 665.27 | |
| New York, No. 1..... | Masonry. | 1851 | 2 003 498.05 | |
| New York, No. 2..... | Timber. | 1890 | 505 019.24 | Rebuilt in concrete, 1900. |
| New York, No. 3..... | Timber. | 1897 | 554 707.08 | |
| New York, No. 4..... | Masonry and Concrete. | Under construction. | 757 800.00 | Body only. |
| League Island, No. 1.. | Timber. | 1891 | 548 700.00 | |
| League Island, No. 2.. | Concrete and Masonry. | Under construction. | 1 301 111.76 | |
| Norfolk, No. 1..... | Masonry. | 1834 | 943 676.00 | |
| Norfolk, No. 2..... | Timber. | 1889 | 504 980.00 | |
| Norfolk, No. 3..... | Concrete and Masonry. | Under construction. | 876 776.00 | Body only. |
| Port Royal, No. 1..... | Timber. | 1895 | 449 437.09 | |
| Mare Island, No. 1.... | Masonry. | 1891 | 2 772 322.08 | |
| Mare Island, No. 2.... | Concrete and Masonry. | Under construction. | 1 385 000.00 | |
| Puget Sound, No. 1... | Timber. | 1896 | 632 636.33 | |
| Charleston, No. 1..... | Concrete and Masonry. | Under construction. | 906 351.86 | Body only. |

FLOATING DOCKS.

| | | | | |
|---|---|---|---|---|
| Algiers..... | Steel. | 1902 | 879 713.52 | |
| *Dewey*..... | Steel. | 1905 | 1 143 959.68 | |

NOTE.—In the case of the Norfolk, No. 3, Charleston, No. 1, and New York, No. 4, docks, the bodies were let independently, the caissons, machinery, and pump wells to follow. Bids on the Charleston caisson were from $105 000 to $85 000; it was estimated, however, that the work could be done at a lower figure by a Navy Yard department, and therefore no contract was awarded.

The cost of the Mare Island and League Island new docks will very probably be increased before being placed in commission.

An important matter to be considered in the first cost of a floating dock is the preparation of the site to receive it. Expensive dredging may be required; and more or less permanent moorings and expensive shore connections must be provided. This work should properly be charged to first cost, in any comparison with the cost of stationary docks.

*Time Required for Construction.*—As regards the time required to construct, it would seem that the floating dock has a decided advantage. The granite dock at Portsmouth, N. H., required 6 years to complete; the granite dock at Boston, 6 years; and the docks

at League Island and Mare Island, contracted for in 1899, are yet unfinished. The small granite dock at Boston Navy Yard was commenced in 1827 and finished in 1833, and the small dock in the New York Navy Yard was under construction from 1841 to 1851. Of the Naval timber docks, No. 3, at the New York Navy Yard, required 5 years; the Port Royal dock, 4 years; and the Puget Sound dock, 4 years.

In a most excellent paper, read before the Institution of Civil Engineers, in August, 1905, by Mr. L. E. Clark, of the firm of Clark and Standfield, the time of construction of a number of floating docks designed by that firm is given; and this information has been used in Table 2:

TABLE 2.—DATA RELATING TO FLOATING DOCKS.

| Dock. | Lifting capacity, in tons. | Weight of hull, in tons. | Date of completion. | Time required to build. |
|---|---|---|---|---|
| At Havana..... | 10 000 | 4 260 | 1897 | 11 months. |
| " Pola..... | 15 000 | 5 200 | 1904 | 23 " |
| " Stettin ..... | 11 000 | 4 002 | 1897 | 7½ " |
| " Port Said.... | 3 000 | 1 514 | 1904 | 3 " |

To which may be added:

| | | | | |
|---|---|---|---|---|
| Algiers..... | 18 000 | 5 850 | 1902 | 27 months. |
| *Dewey* ..... | 20 000 | 9 200 | 1905 | 23 " |

Of course, the time element, as well as every other factor which enters into the question, is largely dependent on local conditions; hence no true generalization can be made.

*Maintenance Charges.*—The granite or concrete dock should require virtually no maintenance, except that due to the ordinary wear and tear on the machinery, caisson, and auxiliary appliances. The floating dock on the other hand, requires constant attention, including frequent self-docking, painting and cleaning. To the ordinary repairs must be added those due to accidents to the hull—an item which cannot be estimated in advance.

The expense of self-docking operations varies with the design and with the ability of the operator, but experience would indicate that it is not necessary to overhaul the bottom of steel docks at smaller intervals than from 5 to 8 years. The old idea that steel is

TABLE 3.—DATA RELATING TO REPAIRS OF DRY DOCKS.*

| Location. | Period. | Dock. | Accessories. | Total. |
|---|---|---|---|---|
| Boston | 1889-99 | $4 158.25 | $55 050.09 | $59 208.34 |
| New York, No. 1 | 1889-99 | 1 815.80 | 11 698.01 | 13 513.81 |
| New York, No. 2 | 1890-99 | In progress, $300 000 expenditure. | | |
| New York, No. 3 | 1897-99 | 171 360.76 | 2 233.63 | 173 594.39 |
| League Island | 1891-99 | 70 721.38 | 7 874.39 | 78 595.77 |
| Norfolk, No. 1 | 1889-99 | 260.20 | 29 912.73 | 30 172.93 |
| Norfolk, No. 2 | 1889-99 | 54 010.77 | 39,432.79 | 93 443.56 |
| Port Royal | 1895-99 | 23 766.72 | 1 664.90 | 25 430.72 |
| Mare Island | 1890-99 | 4 363.62 | 19 912.63 | 24 276.25 |
| Puget Sound | 1897-99 | 328.12 | 11 025.00 | 11 353.12 |

* Annual Report of Chief of Bureau of Yards and Docks, 1899.

more liable to injury by corrosion in sea water than iron, seems to be losing ground; and authorities are not wanting for the statement that there is little, if any, difference in the deterioration of the two metals, if the steel has first been thoroughly cleansed of mill-scale. Indeed, no less an authority than Sir William H. White has given his experience as follows:

"If the manufacturer's scale (black oxide) is entirely removed, and equal care taken in protecting the surfaces with paint or composition, iron and steel have about the same rate of corrosion, the steel wearing somewhat more uniformly than the iron."

As a floating dock is not intended to show speed qualities, the bottom is ordinarily only cleaned for the purpose of protecting the plating. A heavy sea-growth, however, seems to afford the best protective covering that can be had, and there is a question as to the advisability of removing it until the increased weight becomes of appreciable importance. The experience of Assistant Naval Constructor W. G. DuBose, U. S. N., in charge of the self-docking of the Pensacola dock (Havana dock), is of great interest. In his official report of the operation, he says:

"The under-water plating of these pontoons was found to be completely covered to a depth of 8 in. or more with a growth of large oysters, barnacles and various shell growths. By weighing the foreign matter from various places on known areas, it was found that the average weight of shell growth on the bottom plating was 9 lb., and on the side plating 4 lb. per sq. ft. The total weight of shell growth removed from these three pontoons was 99 tons. In addition, it is estimated that about 30 tons of mud, scale and other dirt was removed from the inside of the pontoons. This growth formed

an almost perfect protection for the plating, which was found to be in excellent condition throughout, with practically no corrosion. It is not believed that self-docking of the dock will again be necessary for at least five or six years."

Based on the experience of the contractors in the acceptance tests, the probable maintenance charges for the *Dewey* could be estimated as follows, assuming that it is thoroughly overhauled every fifth year:

| | |
|---|---|
| Expense of self-docking | $10 000 |
| Three coats of paint complete | 27 000 |
| Cleaning bottom | 1 000 |
| Cleaning interior | 2 000 |
| Maintenance of fixed equipment | 5 000 |
| Total | $45 000 |

For one year, $9 000, or 0.72% of the first cost.

The average cost of maintenance of nine docks, cited by Mr. Clark in the paper referred to above, is 1.12% of the first cost. As Mr. Clark has done more to advance floating-dock design than any other one person, and, as he has had ample opportunity for observing a large number of docks built according to the designs of his firm, his experience must be regarded as of great value.

*Operating Expenses.*—The attendance required in docking a cruiser of the *Colorado* class in a stationary dock is slightly less than that for docking the same ship in a floating dock. On a floating dock, an engineer and fireman are required for each pumping element, besides one or two valve men, whereas the pumping-plant of a dry dock would require only one man—with the proper proportion of the expense of the central power plant. The quantity of water to be removed from a dry dock depends upon the size of the ship docked, and is greater for the small ship than for the large one; while, in the case of the floating dock, the pumping required is directly proportional to the weight lifted. On this account, the first cost of a pumping plant required to dock a maximum ship and a minimum ship in a specified time would be greater for the dry dock, and the coal consumption should also be greater. As a matter of fact, however, the coal consumption depends so much upon the operator that little benefit can be derived from comparisons.

As the most economical condition for pumping, in the case of a dry dock, is when docking the largest ship it is capable of holding, the following comparison of the quantity of water to be removed in both types is based on the U. S. S. *Colorado*, as docked by the *Dewey*, and the case of the same ship, if docked in Dry Dock No. 4 (now under construction) at the New York Navy Yard. As the *Colorado* is 504 ft. between perpendiculars, and as the dry dock in question is only 550 ft. on the floor, it will be seen that the dock prism is about as nearly filled as practicable.

*Dry Dock No. 4, New York Navy Yard:*

| | | |
|---|---|---|
| Total water contained in prism of dock. | 58 700 | tons. |
| Displacement of *Colorado* in docking trim. | 13 500 | " |
| Water to be removed in docking..... | 45 200 | " |
| Water to be removed to arrange blocks after docking ..... | 58 700 | " |
| Total water to be removed..... | 103 900 | " |

*Floating Dry Dock, Dewey:*

| | | |
|---|---|---|
| Total water pumped from floating dock *Dewey* from 30 ft. over deck, raising *Colorado* to 2 ft. freeboard..... | 28 700 | tons. |
| Total weight of water removed to bring dock to 2 ft. freeboard after docking. | 15 200 | " |
| Total water pumped..... | 43 900 | " |
| Difference in favor of floating dock.... | 60 000 | " |

Or, in other words, the comparison, under the most favorable circumstances to the dry dock, would indicate that the water pumped in the case of the floating structure would be about 42% of that from the stationary dock.

*Location.*—The cost of a dry dock depends upon the nature of the foundation. Good solid rock foundation is not obtainable in all localities; and when, as is the case at the New York Navy Yard, a

soft bottom underlaid by a water-bearing stratum of fine sand is encountered, or, as at Bermuda, the problem of founding on coral is presented, the building of a suitable dry dock involves great expense and much uncertainty. On the other hand, the floating dock requires for its operation a depth of water considerably greater than the dry dock, and, if the proposed site has not this depth of water naturally, expensive dredging operations must be allowed for in the estimates. If the water is silt-depositing, the cost of maintaining the desired depth must also enter the final decision as a factor.

It has been pointed out that there is an advantage in warping a vessel into a floating dock lying parallel to the shore in a strong current. While this is very probably a real advantage, it is, in some cases, more than offset by the saving in valuable frontage by the use of a dry dock. Undoubtedly, there are times, however, when, for one reason or another, it is desirable to change the location of a yard, and, under such circumstances, the mobility of the floating dock might save the cost of the entire plant.

*Safety.*—As regards the safety of the ship docked, the dry dock has an advantage which at first glance appears to be of great moment, but which on closer study of service conditions would seem to be reduced to a minimum in the latest types of floating docks. It is true that when a ship is safely seated in a dry dock, there is small chance of accident from the structure itself. Indeed, if the dock is well founded, this risk may be regarded as limited to caisson accidents alone. A vessel on a floating dock, however, may be jeopardized in a number of ways, such, for instance, as inherent weakness of the structure itself, injury to the dock by collision, careless handling of valves, faulty moorings, etc. All these dangers have been the subject of careful study, and, in the latest designs, simplicity of operation and uniform strength with a large factor of safety have been sought, and, judging by the recent tests of the floating dock at Algiers and the floating dock, *Dewey,* have been attained to a very satisfying degree.

Commercial ship owners seem to prefer the floating dock, on account of its greater flexibility, which enables it to lift a ship in a condition approaching that in which it rests in the water. If a ship with a sag in the keel is placed on a rigid floor, as in a dry dock, it is deformed by the amount of the sag, and unusual strains are

induced; while the flexibility of the floating dock would permit it to assume the shape of the keel, and, by proper manipulation of the valves, the ship can be given either a hog or a sag. The warship, on the other hand, because of its delicate structure, demands that a perfectly rigid base be provided in docking. As an indication of the approach to this requirement attained in practice, it may be stated that the U. S. S. *Colorado*, 14 500 tons, 504 ft. long, caused a maximum deflection, in the length of the *Dewey*, of $1\frac{1}{16}$ in., while the shorter battleship, *Iowa*, 11 400 tons, caused a maximum deflection in the same dock of 4 in.

Besides those mentioned above, other considerations often enter into the choice of types, among which may be mentioned the strategic value of mobility, possibilities of protection from the attacks of an enemy, possibilities of expansion for future demand, and facilities for affording light and air. The strategic value of mobility has been ably discussed by Civil Engineer A. C. Cunningham, U. S. N., in an article entitled "The Movable Base,"* from which the following is quoted:

"By placing a thoroughly developed military floating dock at each of our naval bases, we may in time of threatened danger double our available bases on the coast by towing the docks to various points of vantage, or in the last extremity if forced to retreat up our rivers and bays, we may take our floating docks with us and establish movable bases that will the sooner enable us to again reach our coasts."

As the dry dock is usually built in the foreshore of a protected harbor, and as the structure proper is below the level of the ground, it is better protected from the fire of an enemy than the floating dock with high towers forming conspicuous targets. A crippled ship would be safer in a dry dock in such a case than in a floating dock, since the latter would not be able to submerge without endangering its charge. The floating dock, however, could be towed farther up the harbor, and anchored in a place of greater safety, and this might more than offset the advantage of the stationary dock.

From a commercial standpoint, much might be said for the floating dock, because of the possibility of starting with a short dock designed so as to be fit for use as a section of a longer dock. If expansion of trade warrants, other sections may be added from time

* *Proceedings* of the Naval Institute, Vol. XXX, No. 1.

to time, and the capital invested in the plant can be kept at a figure more nearly proportional to the earning capacity.

In working under a ship, light is a matter of necessity, and in masonry docks, especially those with small side-wall batter, this object is not always obtained in a satisfactory manner. Paint will not dry quickly or thoroughly in poorly ventilated places, nor are workmen thus situated satisfied or efficient. In both these respects, the floating dock has a great advantage. The dry dock, however, has an equal advantage when it comes to handling material, heavy pieces of machinery, guns, etc. It is practically impossible to install traveling cranes of any considerable capacity on the narrow walls of a floating dock without interfering with the handling of the lines to such an extent as to render them undesirable. All material must come to a floating dock by bridge, wharf or float, and in neither case can the work be done as conveniently nor as economically as in the case of the dry dock, where cranes of from 40 to 100 tons capacity may encircle the excavation, and yard railways communicate with nearby shops.

There is, however, one particular in which the floating dock has a most important advantage over stationary docks, from a naval point of view. A dry dock can never dock a ship with a draft exceeding the greatest depth of water over the blocks, whereas a floating dock can be submerged to within a short distance of its side-wall decks. This advantage may be realized in comparing the *Dewey,* which can safely be given a depth of 37 ft. over 4-ft. keel blocks, while the side walls retain a freeboard of 4 ft., with the deepest naval dry dock (Norfolk dock No. 3, under construction), which will have a maximum depth of 32 ft. over the blocks. By docking on 3-ft. keel blocks, the depth of water on the *Dewey* could be increased to 38 ft. In an emergency such as the accidental disabling of a ship, so as to bring her down considerably by the bow or stern, this advantage of the floating dock might be the means of saving an investment of millions of dollars from total loss.

In passing from this part of the discussion, it may be worth while to draw attention to the fact that sewage can be easily and safely carried from a ship in a floating dock by pipes suspended beneath the ship's scuppers and led overboard through the side walls. This arrangement enables the ship's crew to be kept on board

and under the supervision of officers, and adds greatly to favorable health conditions in tropical stations.

*Types of Steel Floating Docks.*—Very complete reviews of floating dock construction have recently appeared in the technical press and the *Transactions* of various engineering societies, among the most comprehensive of which may be mentioned that contained in "The Cavite Floating Dock"* by Civil Engineer A. C. Cunningham, U. S. N., and Mr. Clark's paper on floating docks previously referred to. It could hardly add to the knowledge of the subject to attempt such a review in this paper, but it may help to a freer discussion if a brief description of the designs marking successive steps in the evolution of the modern floating dock be given.

The earliest design consisted of a vessel of rounded form approximating the shape of a ship. This vessel was permanently closed at one end and fitted with a movable gate at the other, and was operated like an ordinary stationary dock. The gate-dock gave way to the round-bottom dock, depending for its lifting power on the buoyancy of its interior compartments alone, and self-docked by careening. The old Bermuda dock is of this type, and is still in use. The solid-trough dock next appeared, and is still much favored for wooden structures of small capacity. Steel docks of this type are sometimes built for fresh-water harbors, but when located in salt water there is usually included in the plant a shore basin for self-docking purposes. This type has many advantages in the way of strength, rigidity and low first cost, and, beyond a doubt, would be the ideal floating dock to-day if the lack of self-docking facilities could be remedied. Many devices have been proposed for getting at the under-water body of the solid dock, but, thus far, none has given sufficient promise of success to warrant adoption. A caisson arrangement for attachment to the bottom has been in use in Holland, but it is not known with what measure of success. The old Carthagena dock is an example of the solid-trough dock.

*Sectional Docks.*—In order to permit of self-docking, the ordinary sectional dock was evolved. It consists of a number of solid-trough sections, of such length that one could dock another, as shown in outline in Fig. 1. The different sections were loosely connected by timber toggles, and the operation of docking required skill

* *Journal*, Am. Soc. Naval Engineers, Vol. XV, No. 2.

and careful attention, in order that each section might take its own share of the load, and all lift in unison. Examples of this dock in timber are very common.

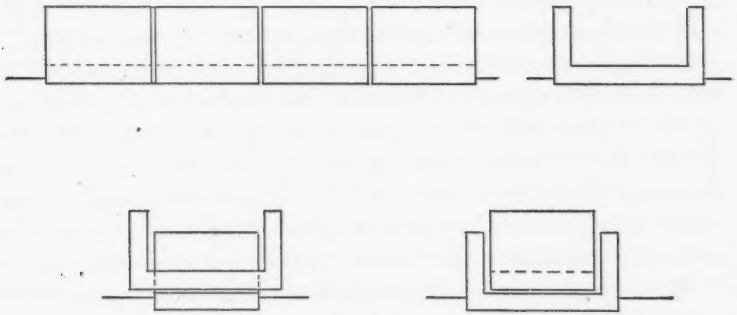


FIG. 1.

*Rennie Type.*—The type designed by Mr. G. B. Rennie, one of the pioneers in floating dock work, consisted of side walls in one piece, forming continuous girders for longitudinal strength, resting on a number of pontoons. This dock could be self-docked by disconnecting a pontoon, turning it so that its breadth lay parallel to the

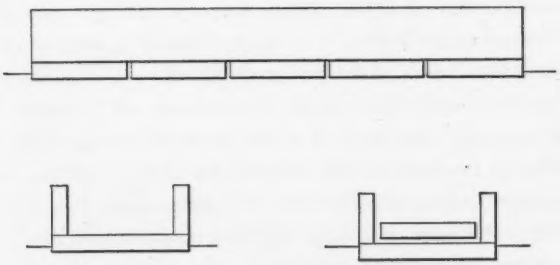


FIG. 2.

axis of the dock, and hauling it over the pontoons remaining in position, as shown in Fig. 2. The 17 000-ton Bloom and Voss dock, at Hamburg, is an example of this type. Its chief objection consists in the fact that it is impracticable to place the pumps in the lowest position on account of the break between the side walls and the pontoons.

*Clark and Standfield Type* (*Havana*).—In this dock, Fig. 3, the side walls are in one piece, but, instead of resting on the pon-

toons, they extend to within a few feet of the full depth of the pontoons, and the latter lie between the former, and are connected thereto by joints made up of fish-plates and bolts. The number of pontoons is unlimited, and the operation of self-docking consists in disconnecting one pontoon at light draft, submerging the dock, bolting the loose pontoon to a second connection diaphragm higher up on the side wall than the regular connection, and pumping to the desired elevation in the regular manner. The side walls are docked by careening. The Havana dock—now Dock No. 2 at the Pensacola Navy Yard—and the new dock at Algiers, La., built by the Maryland Steel Company, are examples of this type. The self-docking operation is entirely practicable, but tedious and rather complicated. The greatest drawback to this type of dock is the difficulty of making

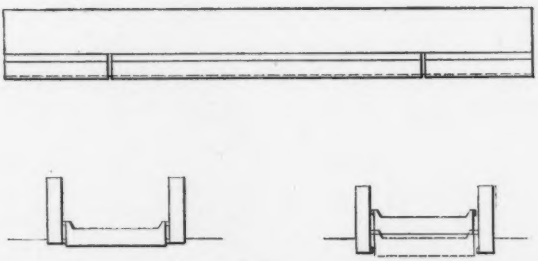


FIG. 3.

it sufficiently rigid to meet naval requirements, the expense of construction, and the inconvenience of self-docking. During the acceptance tests of the Algiers dock, the self-docking was successfully accomplished in 40 days, the pontoons being lifted 4 ft., and the side walls 21 in. above the water.

*Clark and Standfield Pola Type.*—This dock, Fig. 4, is sectional, and each section is a solid trough with side walls and pontoons in one piece. The connections between the sections are made by bolts through flange angles which run around the edges of the transverse faces. To make the joint water-tight, rubber gaskets are placed between the flanges. The method of disconnecting, as described by the inventor, consists in removing the upper bolts while the lower bolts remain in place; the outer ends of the pontoons are then water-ballasted, causing the sections to press together at the bottom, and

thus enabling workmen to enter and remove the remaining bolts in the dry. For self-docking purposes, the side walls are cut away for a short distance on the bow and stern sections, and these portions of the pontoon deck are drawn under the third section, as shown in the sketch. It is claimed by the inventor that, as each section is built solid, and they are connected all around their contact edges, it is the strongest self-docking dock—a claim which probably held good at the time it was invented, though, in the matter of strength, it could hardly be compared with the *Dewey* of later date. Whether or not the Pola dock, the only one thus far constructed on this plan, has been self-docked is not now known, but it would certainly appear to be a difficult matter to keep the connection chambers free from water; and the removal of bolts might be attended with some danger.

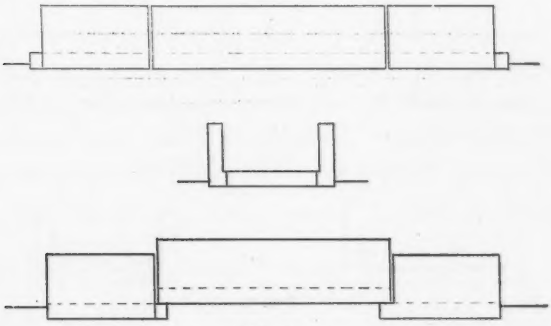


FIG. 4.

Holding the docked pontoon on the narrow ledge of deck available, would be out of the question in anything but perfectly still water, and, under the most favorable conditions, self-docking would require very skilful handling.

*The Cunningham Sectional Dock.*—This dock, Fig. 5, developed and patented by Civil Engineer A. C. Cunningham, U. S. Navy, consists of solid-trough sections joined together by fish-plates and bolts. The self-docking is effected by connecting two of the sections to the third by diaphragms, placed for the purpose at a higher elevation than those ordinarily used. This dock claims the advantage of having exactly similar elements, thus permitting expansion at any time by the addition of sections. The connections can be made of sufficient strength for naval requirements, and the self-docking oper-

ation is a very simple matter. This type should, and doubtless will, prove especially attractive for commercial purposes.

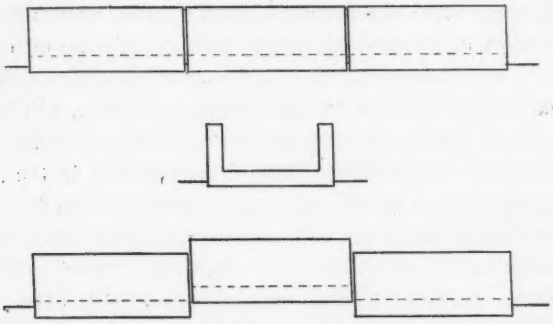


FIG. 5.

*Maryland Steel Company Type.*—This type of dock, originated and patented by Mr. Henrik F. Hansson, consists of a main pontoon of solid-trough section, with side walls extending beyond its length and bearing directly on the decks of the two shorter end pontoons. The end pontoons have low independent side walls, to afford sta-

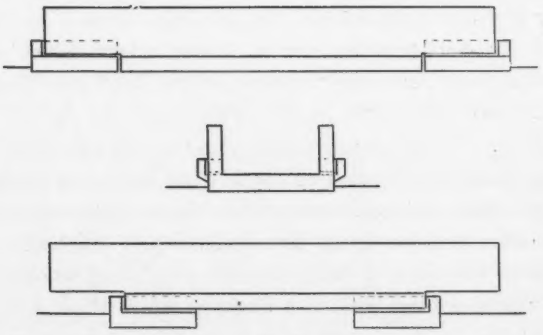


FIG. 6.

bility in self-docking operations, and contain independent pumping plants. In self-docking, the center pontoon takes both end pontoons on the blocks in the regular manner, and, to dock the center pontoon, the bow and stern pontoons are drawn under its ends, as shown in Fig. 6. This arrangement, with its long solid main section, gives nearly the strength and rigidity of the solid-trough dock, and is the simplest of all types in its self-docking operations.

## Design of a Floating Dock.

Instead of discussing in general the principles governing the design of a floating dock, it is believed that the example of a dock actually constructed will prove of greater value in forming the basis for discussion of the subject, and, with this in view, a rather detailed account of the inception, design and construction of the U. S. floating dock *Dewey*, intended for the Philippine service, will be given.

*Choice of Dock.*—In 1902, the date of the act authorizing the construction of the dock, the Philippines had been in the possession of the United States for five years, and the necessity of maintaining a fleet in Philippine waters had been recognized for some time. The old Spanish naval station at Cavite was badly located, and Congress hesitated to authorize further expenditure at this place until the question of a site for a permanent station had been settled. The need for docking facilities in the Philippines was urgent, as without them a voyage to Hongkong, Kobe or Yokohama was a periodical necessity for every ship of the squadron. If a large investment were to be tied up in docking facilities, it was desirable to obtain a structure which could be moved, should future developments render such a step advisable. Again, the Department's experience with masonry dry docks established the fact that from 5 to 7 years are required for construction here at home, where labor conditions, prices of material, etc., are known, and the 18 000-ton floating dock at Algiers was constructed in 27 months from the date of awarding the contract. These considerations alone would have been sufficient to have caused the adoption of the floating dock, but other features of the type were so happily adapted to the requirements of the case that no other decision could have been wisely reached. Not least among them was the fact that a floating dock could be equipped with a small machine shop, and in a location where there are no shops, contain within itself an outfit for making all minor repairs.

*The Specification.*—The Bureau of Yards and Docks, in whose province lay the carrying out of the terms of the act, had just built the floating dock at Algiers, La., a structure which represented the highest progress then attained in dock building, and, with the idea of obtaining the very best results, decided to leave the design to open competition under a general specification. This specification was drawn up by Civil Engineer A. C. Cunningham, U. S. Navy, whose

experience as officer in charge of the Algiers dock gave him a peculiar fitness for the task. The result was a specification, acknowledged to be the most complete ever written for a structure of this kind. Paragraphs setting forth requirements, the knowledge of which is necessary to a complete understanding of the detailed design, are given herewith.

EXTRACTS FROM THE SPECIFICATION FOR THE CAVITE SELF-DOCKING STEEL FLOATING DRY DOCK.

"*1. Intention.*—It is the declared and acknowledged intention and meaning to provide and secure a complete and substantial self-docking floating steel dry dock of American manufacture suitable for docking all of the present and projected ships of the United States Navy, for which appropriations have been made, located and installed in complete and perfect working order, together with all moorings, wharves, approaches, accessories, and appurtenances necessary for its perfect, complete, and convenient operation and maintenance, to the entire satisfaction of the Chief of Bureau of Yards and Docks.

"*9. Time of completion.*—The dock proper shall be entirely completed and ready for test in every respect and particular within twenty-seven calendar months from the date of the contract.

"*23. Plans and specification.*—General plans in sufficient detail to give the Bureau a perfect understanding of the design of the dock, its method of operation, manipulation, and construction, and of the character and distribution of all material, machinery, and appliances shall be furnished by bidders. The general plans shall be accompanied by a specification, stress diagrams, and calculations in further amplification of the design and its capabilities, with full explanations of all operations and manipulations. The character and make of all machinery and appliances shall be described in the specification, and all other details necessary to enable the Bureau to arrive at a correct and perfect understanding of what is proposed. The contractor shall furnish the Bureau with tracings of all general plans.

"*24. Detail plans.*—The contractor shall prepare detail plans in amplification of general plans showing all parts of the dock and its appliances. Triplicate blue prints of these plans shall be submitted to the officer in charge for examination and approval before any work is performed. Tracings of approved plans shall be furnished to the Bureau. Approval of detail plans shall be of a general nature and shall not relieve the contractor from errors, discrepancies, or omissions that may occur therein which shall be remedied or supplied whenever discovered or required.

"*31.*—The location of the dock is at the Naval Station, Cavite, P. I., at a site to be selected, but the Government reserves the right to reasonably vary the location as may be to its best interests before the final acceptance of the dock. The contractor shall provide moorings, approaches, and other necessary accessories and appurtenances suitable for the location finally selected by the Government.

"*32. General description.*—The dock in general shall be an open-hearth steel structure, so designed and arranged as to be readily self-docking without the aid of divers or auxiliary constructions. It shall be self-contained as to operating machinery, and capable of being towed from place to place safely without auxiliary bracing. It shall be of the general type composed of watertight side walls and body, or pontoons, with a general ⊔-shaped cross section, and divided into sufficient water-tight compartments to give great stability, there being not less than 6 transversely. Simplicity and certainty of operation and freedom from possible disablement in all operations should be given careful consideration by designers.

"*33. Length.*—The dock shall be not less than 500 feet long over all, none of which length shall consist of bracketed platforms without lifting power.

"*34. Width.*—The dock shall have a clear width between fenders of not less than 100 feet.

"*35. Height and draft.*—The decks of side walls shall have not less than 8 feet of clear height above the water, with 30 feet draft over 4-foot keel blocks.

"*36. Lifting capacity.*—The dock shall have a lifting capacity of not less than 16 000 gross tons, uniformly distributed over its entire length, with the main deck not less than 2 feet above the water and with not less than 1 foot of water in the compartments.

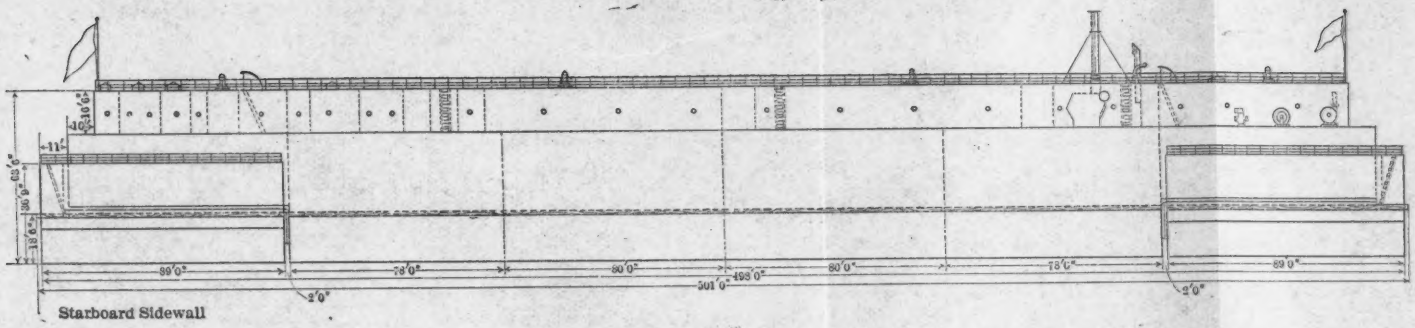
"*37. Unit stress.*—No portion of the dock, or its connections, shall have a stress of more than 10 000 pounds per square inch under the specified loads, or of 15 000 pounds per square inch in self-docking, with a wind pressure of 30 pounds per square foot of exposed surface.

"*38. Shiploads.*—The dock shall be designed to dock all classes of vessels of the United States Navy, either centrally or with the center line of the keel 1 foot off the center line of the dock, with a free board of 2 feet, and shall provide for bearing over the full length of dock. Diagrams of weights, as far as available, will be furnished on application.

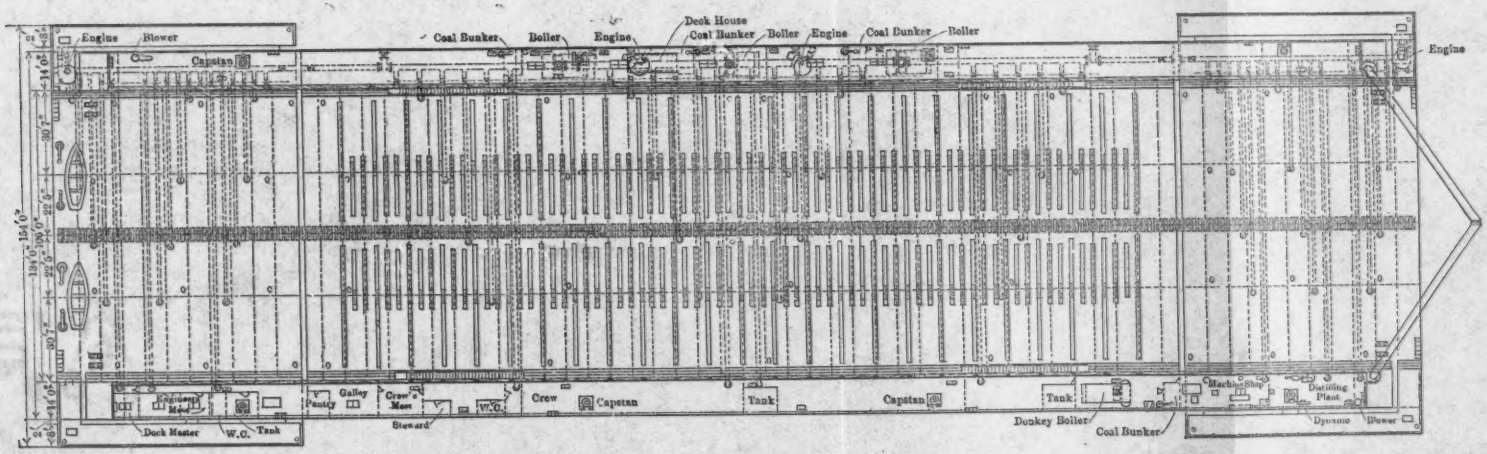
"*39. Distribution of load.*—The dock shall be so designed that the entire weight of a battle ship may be safely carried by the main keel blocks, or one-half the weight on each line of docking keel

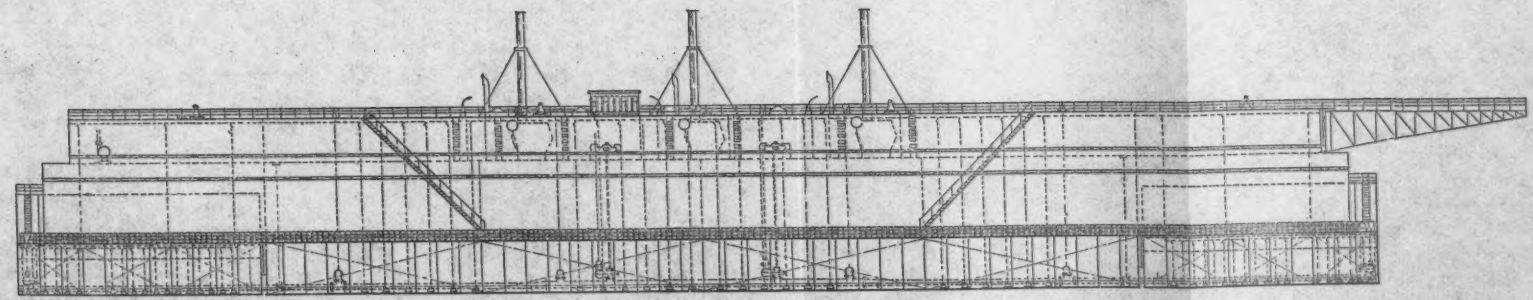
# PROPOSED SELF-DOCKING STEEL FLOATING DOCK OF 16,000 TONS CAPACITY

## FOR U. S. NAVAL STATION, CAVITE, P. I.




Starboard Sidewall



Port Sidewall

GENERAL ARRANGEMENT

blocks, in whichever position the ship may be docked. The side walls shall be designed to take shoring at any point that may be necessary.

"*40. Working deck.*—The working deck of the dock shall be flush-plated and so strengthened that docking keel blocks may be placed in any position.

"*41. Uniform pumping.*—The dock shall be so designed that the specified unit stress shall not be exceeded when the dock is pumped uniformly from all compartments to a free board of 2 feet with any specified shipload docked centrally.

"*42. Allowable deflection.*—With any specified shipload docked centrally and all compartments pumped uniformly until the dock has a free board of 2 feet, the longitudinal and lateral deflection over the entire working deck of the dock shall not exceed 1 in 2 000. Within the limits of allowed deflection the shipload shall be assumed to be perfectly flexible.

"*43. Keel blocks.*—All keel blocks shall be of clear heart oak, of a uniform length of 5 feet, a width of 16 inches, and planed to a uniform thickness of 12 inches so as to be interchangeable.

"*44. Spacing of blocks.*—Main keel blocks shall be spaced 2 feet on centers and docking keel blocks 4 feet on centers.

"*45. Block sills.*—Docking keel blocks shall rest on sills of clear heart long-leaf yellow pine, 16 inches wide and planed to a uniform thickness of 12 inches so as to be interchangeable. The sills shall be of sufficient length to accommodate all the docking keels in the Navy.

"*46. Sliding blocks.*—Every third sill shall be fitted with a sliding block, and shall extend to within 2 feet of the main blocking and sufficiently outboard so that the blocks can not be hauled off the sill.

"*47. Drainage.*—Athwart-ship and fore-and-aft drainage shall be provided on the working deck of the dock.

"*48. Side wall decks.*—The decks of side walls shall have a clear passage fore and aft of not less than 5 feet in width. They shall have a hand rail on the outboard side and a 12 by 16-inch clear heart yellow pine timber on the inside fitted with fair leads and cleats.

"*49. Passage.*—Passage from one side wall to the other shall be provided.

"*50. Communication.*—Telephone or speaking tube communication shall be provided from one side wall of the dock to the other, along the side walls, and to the engine rooms.

"*51. Headline.*—Provision shall be made for a central headline and for hauling the same from side walls.

"*52. Capstans, winches, and bitts.*—There shall be not less than

four capstans on each side wall and the necessary capstans or winches for handling moorings. There shall be not less than eight bitts on each side wall.

"*53. Moorings.*—Two sets of moorings shall be provided at each corner of the dock.

"*54. Runways and shoring stages.*—Two lines of runway and shoring stages not less than 36 inches wide shall be provided on the inner side of each side wall and a runway about 2 feet above the main deck.

"*55. Ladders and steps.*—Access shall be had to the runways and shoring stages by suitable ladders and steps from the top of side walls and main deck.

"*56. Fenders.*—All parts of the dock liable to be fouled by a ship in docking shall be fitted with heavy rubbing timbers and fenders, so arranged as to not injure the dock if carried away and to be readily replaceable. The exterior of the dock shall be fitted with fenders and rubbing timbers as a protection from drift and fouling.

"*57. Fire service.*—A fire service and washing-down system shall be provided the entire length of each side wall at or near the top, and with not less than four hose connections on each side.

"*58. Indicator system.*—The dock shall be fitted with a reliable pneumatic or hydraulic indicator system to show the depth of water in all compartments at all times.

"*59. Levels and gauges.*—The dock shall be fitted with levels and gauge boards to indicate the trim.

"*60. Height of self-docking.*—When self-docked, all under-water portions shall be raised to a clear height of not less than 5 feet, and shall be safely and readily accessible for inspection, painting, and repairs.

"*61. Self-docking connections.*—With the dock at light-draft line, all self-docking and strain-transmission connections shall be above water.

"*62. Power.*—The dock shall be operated by steam power, and shall be fitted with all the necessary boilers, engines, pumps, feed-water heaters, steam separators, and other accessories desirable to make a first-class self-contained plant.

"*63. Boilers and engines.*—There shall be not less than 600 nominal horsepower of boilers and engines suitably distributed to give the best results. Simplicity and certainty of action and freedom from possible breakdown in operation are to be given the first consideration. Engines of a type and style which will produce the least vibration in the side walls are desired.

"*64. Main pumps.*—If of the centrifugal variety, the main pumps shall have a discharge of not less than 16 inches and an equivalent discharge for other varieties.

"65. *Piping.*—All piping shall be of ample size to supply the pumps at maximum speed, and so installed as to be readily accessible for repairs or renewal.

"66. *Valves.*—The piping and flow of water shall be completely controlled by a system of simple and durable bronze-mounted valves, of the wedge variety, of easy and certain operation. All valves shall be fitted with indicators.

"67. *Fuel and water.*—Storage shall be provided for fuel and fresh water sufficient for two complete successive dockings, of the maximum load.

"68. *Connections to ship.*—Provisions shall be made for supplying a ship in dock with water and for carrying off her waste water and sewage.

"69. *Machine shop.*—A small machine shop, suitable for light repairs to the dock, shall be installed in one side wall.

"70. *Storerooms and quarters.*—Such portions of the side walls above the engine decks as are not occupied by machinery shall be fitted as storerooms, and as quarters for the dock's officers and crew, with suitable mess arrangements.

"71. *Hatches, skylights, deadlights, and ladders.*—The side walls shall be fitted with all the necessary hatches, skylights, deadlights, ladders, and other conveniences necessary or desirable.

"72. *Lighting plant.*—An electric-light plant shall be installed on the dock for lighting all interior working and storage compartments and with connections for portable lights on the dock.

"73. *Ventilating system.*—A blower system shall be installed for ventilation of all working and storage spaces and quarters in the dock.

"74. *Time of operation.*—The dock shall be designed to lift a load of 16 000 gross tons, with a draft of 30 feet clear of the water, in 4 hours. Lighter loads of less draft shall be lifted in a correspondingly shorter time, and the pumps shall readily operate under a head of 35 feet. The time of operation will be reckoned from when the ship has taken the blocks and shores and pumping is commenced until the keel is out of water.

"75. *Place of tests.*—All docking and self-docking tests shall be made at a suitable and convenient place at or near the works of the contractor.

"76. *Preliminary tests.*—Preliminary tests in sinking and raising the dock and in operating all machinery shall be made by the contractor to satisfy the officer in charge that the dock is in perfect working order.

"77. *Cruiser test.*—The dock shall be tested in docking a cruiser furnished by the Government, centrally or off line, as specified.

"*78. Battle-ship test.*—The dock shall be tested in docking a battle ship furnished by the Government, centrally or off line, as specified.

"*79. Deflections.*—Observations shall be made for deflection and permanent set during the dockings, with specially designed instruments furnished by the contractor, which will become part of the dock's outfit. In determining the final deflection, allowance shall be made for permanent set and temperature deflection, and the blocking shall be straight.

"*80. Self-docking tests.*—The dock shall be completely self-docked upon the completion of the docking tests.

"*81. Board of tests.*—The tests shall be conducted by a board of naval officers, appointed by the Secretary of the Navy, one of whom shall be a line officer expert in steam engineering, one a naval constructor, and one a civil engineer. The dock will be carefully examined by the board and tested for all specified requirements.

"*82. Conduct of tests.*—In docking naval vessels the ships shall be maneuvered, entered, and placed in position in the dock by the commanding officer and the naval constructor of the board, according to naval practice, with tugs and labor furnished by the contractor. All preparations and manipulations of the dock in testing shall be conducted by the contractor to the satisfaction of the board. A mutual understanding and agreement shall be had by the board and contractor preceding docking tests, to prevent accidents to the ship or dock.

"*83. Duration of battle-ship test.*—On the last test the battle ship shall be carried centrally on the dock for 48 hours without the dock showing any undue signs of strain or fatigue.

"*84. Condition on delivery.*—If the dock is delivered by the contractor at Cavite, all machinery, valves, strain-transmission, and self-docking connections shall be put in perfect working order before the dock is turned over to the Government.

"*85. Docking material.*—All the necessary material and appliances needed in testing and operating the dock shall be supplied by the contractor and become part of the dock's outfit.

"*86. Dock equipment.*—The dock shall be provided with all conveniences for operation, manipulation, and self-docking.

"*87. Boats*—Two 20-foot metallic lifeboats with complete equipment shall be provided with the dock.

*Materials.*

"*88. Quality.*—All materials and workmanship shall be of the best quality of their respective kinds when the grade is not specifically mentioned, and the acceptance of same is understood and agreed to be subject to the approval of the officer in charge.

*Structural Steel and Iron.*

"*89.*—The steel for this work shall be made by the open-hearth process.

"*90. Structural steel.*—Structural steel shall have a maximum tensile strength of 55 000 to 65 000 pounds per square inch, an elastic limit of not less than one-half the maximum tensile strength, an elongation of not less than 23 per cent in 8 inches. It shall bend when cold 180 degrees around its thickness and when at or above a red heat 180 degrees flat, all without rupture on outside of bent portion.

"*91. Rivet steel.*—Rivet steel shall have a maximum tensile strength of 47 000 to 55 000 pounds per square inch, an elastic limit of not less than one-half the maximum tensile strength, an elongation of not less than 25 per cent in 8 inches. It shall bend when hot, cold, or quenched in water of 70° F. 180 degrees flat, all without rupture on outside of bent portion.

"*92. Steel castings.*—Steel castings, after annealing, shall have a maximum tensile strength of not less than 60 000 pounds per square inch, an elongation of not less than 15 per cent in 2 inches. They shall bend when cold 90 degrees around three times their thickness and when at or above a red heat 180 degrees flat, all without rupture on outside of bent portion.

"*93. Phosphorus and sulphur limits for steel.*—Acid open-hearth steel shall not contain more than eight one-hundredths of 1 per cent of phosphorus, and basic open-hearth not more than five-hundredths of 1 per cent. No steel shall contain more than five one-hundredths of 1 per cent of sulphur.

"*94. Identification of steel.*—All steel shall be stamped with its cast number.

"*95. Wrought iron.*—Wrought iron shall be tough, ductile, fibrous, and free from steel scrap. It shall have a maximum tensile strength of not less than 48 000 pounds per square inch, an elastic limit of not less than one-half the maximum tensile strength, an elongation of not less than 12 per cent in 8 inches. It shall bend when cold 90 degrees around three times its thickness and when at or above a red heat 180 degrees flat, all without rupture on outside of bent portion.

"*96. Iron castings.*—Iron castings shall be made of the best quality of tough gray foundry iron and shall have a maximum tensile strength of not less than 18 000 pounds per square inch.

"*97. Tests of iron and steel.*—All tests shall be selected by a Government inspector. For steel there shall be not less than one of each kind for determining the physical and chemical qualities of each cast, and for iron a sufficient number to determine the quality of the lot under inspection.

"*98. Variations.*—Rolled material shall not vary more than 2½ per cent from section or weight ordered, except in the case of wide sheared plates, where standard variations will be allowed; castings shall be true to drawings.

"*99. Defects.*—All rolled and cast material shall be free from defects and imperfections and true to section.

"*100. Inspection of steel and iron.*—All steel and iron shall be tested and inspected by a Government inspector at the place of manufacture before shipment. Orders for steel and iron shall be marked "Inspection by Bureau of Yards and Docks, Navy Department," and triplicate copies shall be forwarded to the Bureau from the shop where the material is ordered in order that the inspection may be arranged, and one copy to the officer in charge for his information. Lists of material offered for inspection (with cast numbers in the case of steel) shall be furnished the inspector by the mill.

*Workmanship.*

"*101. General character.*—All members and parts shall be manufactured and finished in a neat and workmanlike manner in accordance with best American ship practice, and to the satisfaction of the officer in charge.

"*102. Details and connections.*—All details and connections shall be designed to develop the full strength of main members and for the greatest possible stiffness. The least number of parts consistent with the best results shall be employed in all details and connections.

"*103. Accessibility.*—All details and connections shall be readily accessible for inspection, painting, and repairs.

"*104. Calking.*—All water-tight work shall be carefully machine-calked as the work progresses and tested in detail as far as possible. The work shall be so designed that all calking edges are accessible in the finished dock.

"*105. Water-tightness.*—The completed dock shall be made perfectly water-tight before acceptance so that it may be held in any position, light or submerged, without settlement.

"*106. Access to interior.*—Easy access to all interior portions of the dock shall be provided.

"*107. Least thickness.*—No material of less than ⅜ inch in thickness shall be used in any portion of the dock which is subject to stress.

"*108. Pitch of rivets.*—In water-tight work the pitch of rivets shall be such as to insure perfect water-tightness, but in no case shall it be less than three diameters, and in general not to exceed 6 inches.

"*109. Rivet holes.*—Rivet holes shall be smoothly punched $\frac{1}{16}$ inch larger than the rivet to be used. When work is assembled the rivet holes shall so closely coincide that the hot rivet shall enter without drifting. Slight mismatching of holes shall be corrected by reaming, provided a perfect hole can be obtained and a correspondingly larger rivet is used.

"*110. Rivets.*—Wherever practicable all rivets shall have button heads on both ends of an approved form, and a sufficient length of shank to completely fill the holes and form perfect concentric heads. Rivets in decks and wherever else necessary shall be countersunk.

"*111. Driving rivets.*—Rivets shall be carefully heated and machine-driven wherever possible, in such manner as to completely fill the holes and form perfect heads.

"*112. Defective rivets.*—Loose, burnt, or imperfect rivets shall be cut out and replaced with satisfactory ones.

"*113. Inspection of workmanship.*—All workmanship, machinery, and appliances shall be inspected at the place of manufacture by a Government inspector.

*Painting.*

"*114. Cleaning metal.*—Before painting, all metal shall be carefully cleaned of all loose scale, rust, grease, dirt, chips, and other foreign matter by hammering, scraping, and brushing with wire brushes.

"*115. Paint.*—The paint in general shall consist of red lead, white zinc, japan dryer, and raw linseed oil, mixed in proportions as directed, and applied in such manner and at such times as directed by the officer in charge.

"*116. Contact surfaces.*—Contact surfaces shall each receive one coat of paint before assembling.

"*117. Painting.*—The entire dock shall receive three coats of paint before launching, and shall be touched up wherever necessary on the completion of the tests. In addition to the general painting, the engine rooms, boiler rooms, and quarters shall be finished as directed in oil paint, ground cork, and cement floors.

"*118. Paint materials.*—All paint materials shall be of approved quality and delivered in original packages.

*Proposals.*

"*119. Certified check and bond.*—Each proposal must be accompanied by a certified check, payable to the Chief of the Bureau of Yards and Docks, for the sum of $25 000, as a guaranty that the bidder will execute the required contract within ten days after its

delivery to him for that purpose, and give a bond (preferably that of a first-class security company) in a penal sum equal to 20 per cent of the contract price, conditioned upon the faithful performance of the contract. Checks of unsuccessful bidders will be returned immediately after the contract is awarded, and of the successful bidder upon the execution of the contract.

"*120. Form of proposals.*—Proposals and all exhibits, alternate plans, letters of explanation, circulars, and all other papers (except the certified check) which it is desired to have considered in connection therewith must be made in duplicate. Proposals shall be made upon the prescribed blanks furnished bidders, as follows:

"*Item 1.*—Price for dock and appurtenances delivered and moored at Cavite ready for operation, and the time required for such delivery.

"*Item 2.*—Price for dock, moorings, and appurtenances delivered at the works of the contractor ready for towing, and insured by the contractor for delivery at Cavite.

"*Item 3.*—Price for the dock, moorings, and appurtenances delivered at the works of the contractor ready for towing, and without insurance.

"*Item 4.*—Price for towing the dock from the works of the contractor and delivering and mooring at Cavite.

"*Item 5.*—In case the bids on any of the above items exceed the appropriation available, an opportunity is given under this item to submit alternate proposals for completing the work within the appropriation.

"*121. Acceptance and rejection of proposals.*—In giving great latitude in the design of the dock, both as to its general features and details, it is the desire of the Government to secure a structure that will fully meet the present and future needs of the naval service in a dock for the safe and convenient docking of all naval vessels, and for safe and convenient preservation and repair of itself; and the Government reserves the right to determine the relative merits of all the designs presented, irrespective of the price bid, and to accept the design which most fully meets its requirements, and to award the contract upon any of the above items, to accept any bid, to waive any defects and informalities in the proposals, and to reject any or all bids.

"*122. Bidder's ability.*—Before he is awarded the contract any bidder may be required to show that he has the necessary facilities, experience, and ability to perform the work in a satisfactory manner.

"*123. Amount of appropriation.*—The appropriation now available is $1 225 000.

"*124. Information.*—For any further information needed by intending bidders, application should be made to the Chief of the Bureau of Yards and Docks.

"NAVY DEPARTMENT,

"BUREAU OF YARDS AND DOCKS, *December, 1902.*"

A careful study of the designs submitted resulted in the award of the contract to the Maryland Steel Company, of Sparrow's Point, Md. The dock proposed has already been described under the name "Maryland Steel Company Type," patented by Henrik F. Hansson, and shown in outline sketch in Fig. 6.

*General Dimensions.*—Paragraphs 33 to 36 of the general specification govern the length, clearance between side walls, minimum draft of water over keel blocks, minimum freeboard, and the lifting capacity. The type of dock adopted required no altar at the junction of the side wall and deck (which was necessary in the Algiers dock for the pontoon connections) and valuable space was gained by omitting that objectionable feature. A side-wall width of 14 ft. was assumed for strength, space and stability considerations. The width of the painting stages was taken at 3 ft., to the outside of the fender, so that the over-all breadth of the dock would be 134 ft.

The skeleton structure of the dock is the result of the assumption that the local ship load is to be transmitted by the transverse members to the side walls, which, extending the full length of the dock, act as longitudinal girders. The ship rests directly upon keel blocks spaced at 2-ft. centers, and sills for bilge blocks are spaced at 4-ft. centers. As it is desirable to have the load placed symmetrically as regards the transverse girders, the position of the bilge sills limits the advantageous girder spacing to 8 ft., since a 4-ft. spacing would require too many, and, for a 12-ft. spacing, the necessary strength could not be obtained.

For preliminary calculations, the load curve of the new 16 000-ton ships was assumed to be made up of a uniform load of 30 tons per lin. ft. over 50 ft. of the keel length at each end, and 50 tons per lin. ft. for the remainder of its length. On this assumption, the loads on the transverse girders, spaced at 8-ft. centers, due to the ship, amount to 400 tons. This load may be considered as applied equally at three points, two points, or one point, according as the ship is assumed to be supported by keel and bilge blocks equally, the

two rows of bilge blocks, or by keel blocks only. The negative loading due to the buoyancy amounts to:

$$\frac{16\,000}{500} \times 8 \times \frac{106}{134} = 202 \text{ tons, uniformly distributed.}$$

The transverse girders are fixed at the ends to the side walls; but, on account of the deformity of the structure as a whole, under stress, the span is taken from the centers of the side-walls, or at 120 ft., and the girder is considered as simply supported; therefore:

The maximum bending moment, ship resting on three blocks, is ..... 5 682 ft-tons.
The maximum bending moment, ship resting on two blocks, is ..... 4 216 " "
The maximum bending moment, ship resting on one block, is ..... 8 616 " "

from which, using the specified unit stress of 4.46 tons per sq. in., the moment of resistance required is 15 290 inch-thirds for the first

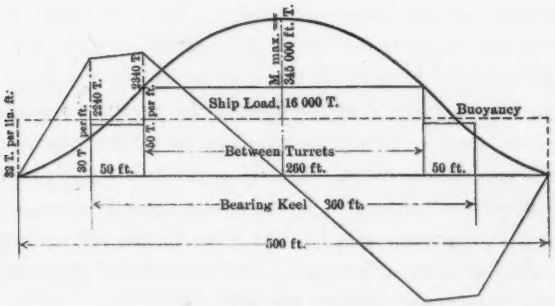



FIG. 7.

case, 11 340 for the second and 23 184 for the third. As the case of a large ship supported by the keel blocks alone would be impossible in actual practice, the required resistance moment in the first case above caused the tentative adoption of 18 ft. as the depth of the pontoons. This, however, was increased to 18 ft. 6 in. as a result of later and more detailed calculations.

Assuming the weight of the dock and machinery to be 11 000 tons, the weight of the dock and the ship is 27 000 tons, to which must be added the weight of 12 in. of contained water, as provided in the specification, making a total of 28 900 tons when the specified

ship is raised to 2 ft. freeboard. The displacement of the pontoons per foot may be taken at 1 900 tons. The depth of pontoons, less the 2 ft. specified freeboard, is 16.5 ft., which at 1 900 tons per ft. gives a buoyancy of 31 350 tons, an ample margin above requirements.

To obtain the required moment of inertia of the dock section as a whole, the bending moment at the center is obtained (Fig. 7) as 345 000 ft-tons; from which the moment of resistance is found to be 928 250 inch-thirds. As it was found impracticable to obtain this resistance with the limiting side-wall requirements set forth in Paragraph 35 of the specifications, and for the further purpose of insuring rigidity, the side-wall freeboard was increased 3 ft. 6 in., making the total depth of the side walls 36 ft. 6 in.

The width of the independent side walls was taken at 8 ft., and increased to 10 ft. on the ends to provide working room for operating the independent pumping plant.

## Hull Details.

*Skin Plating.*—The displacement per foot, based on the above general dimensions, is 1 900 tons for the pontoons and side walls to the level of the main deck. The displacement per foot of both side walls is 380 tons. When the dock is at its maximum submergence (34 ft. of water over deck) the displacement would be 48 480 tons, assuming that the independent side walls, except engine rooms, admit of a free flow of water. Taking the weight of the dock at 11 400 tons, and assuming that 12 in. of air remain in the pontoons, the water in the side walls will rise to 9 ft. above the deck, or 25 ft. below the water line. If no air is assumed to be left in the pontoon, the water will rise to 5.1 ft. in the side walls leaving 28.9 ft. head on the side-wall plating—a maximum head for side-wall plating. The maximum head on the bottom plating occurs when 12 in. of air is considered as remaining under the deck, and amounts to 35 ft.

All attempts to derive a rational formula for the stress in flat plates have resulted in complicated expressions too cumbersome for practical use, and the paucity of experimental data on plates of the size commonly used and under conditions approaching actual service has, so far, prevented the discovery of a satisfactory empirical formula. About all that is definitely known on the subject, at present, is that rectangular plates attached to frame angles by good

riveting are subjected to a bending stress up to a certain point, after which the character of the stress changes to something like that which obtains in a loaded chain.

Experience in the use of plates under water loading would indicate that there is little danger of actual failure under a static loading due to the range of heads with which the designer has to do, and that the methods used in current practice afford an ample margin to cover all dynamic loading. It is here suggested that if ship-builders would adopt a maximum permissible deflection, expressed as a percentage of the shortest dimension of the unsupported rectangle of the skin plating, a satisfactory empirical formula might be derived from experiments on full-sized units, to which an impact factor could be added to provide for wave effect. Such a formula, if generally adopted, would not change present practice further than to provide uniformity of method.

To determine the thickness of the skin plating on the *Dewey*, an elementary beam, 1 in. in width, was considered as fixed at the ends and supported at the edges of frame angles. If $K$ represents the allowed intensity of stress, $H$, the head of water, in feet, and $l$, the span, the expression for the thickness may be written:

$$t = 0.0001 \frac{H\, t^2}{K}.$$

Using the dimensions shown in Fig. 8 for a beam 1 in. wide, having a thickness, $t$; and a span of 21 in., under a 35-ft. head of water:

$$\text{Then, } t = 0.586 \text{ in.} = \tfrac{19}{32} \text{ in.}$$

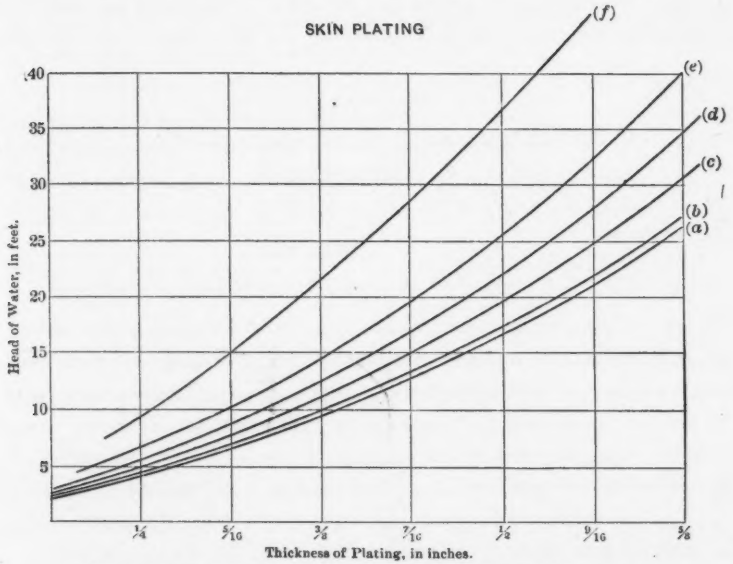



FIG. 8.

This method does not take into account the metal lost by punching, nor does it seem to be rational to take the span as the distance between the edges of the supports, because any deformation of the flanges will destroy the usefulness of the flexure formulas.

Experiments on full-sized plates, which were conducted during the construction of the dock (the results of which may be submitted

to the profession at a later date), would indicate that the actual deflection is from one-third to one-fifth of that obtained by the fixed-beam formula, and that a considerable excess of strength is obtained by its use. It should be stated that these experiments were on plates supported only at their edges and not continuous over the supports. Therefore, they do not show the effect of continuity, nor do they indicate the effect of the ship's distortion as a whole.




(*a*) Fixed beam formula, Span 21', ¾" rivets, 6" Spacing deducted (⅞" gross hole)
(*b*) " " " " " " " " " " (net rivet area)
(*c*) Rectangular plate formula. $K = wa^4b^2 \div 2\ t^2\ (a^4 + b^4)$
(*d*) " " " Bach, $t^2 = 0.468\ wa^2b^2 \div K\ (a^2 + b^2)$
(*e*) Fixed-beam formula, Span 21', no rivets deducted.
(*f*) Experimental,- deflection= 1/360 Span

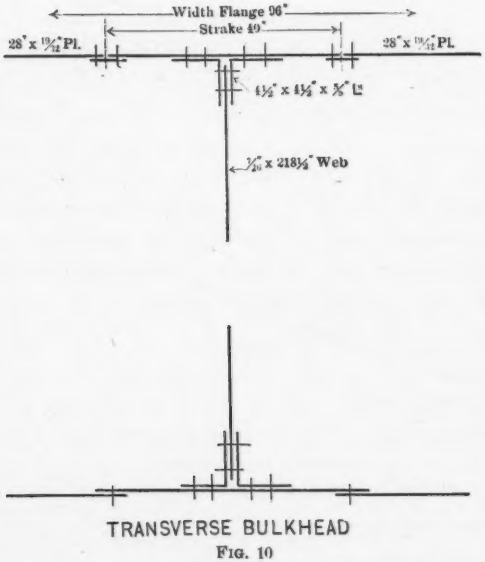
FIG. 9.

Fig. 9 shows the curve of thickness required for different heads, as obtained by the fixed-beam formula, Bach's formula for rectangular plates, and other well-known formulas. As a matter of interest, a curve is added showing the thickness obtained by limiting the deflection to $\frac{1}{360}$ of the span, as determined by the experiments referred to above.

If the lap is considered as a beam supporting two edges of a rectangular section of plating, a slightly less degree of thickness is

required by the use of Bach's formula. Taking the lap at $2\frac{1}{2}$ in. in width, and deducting rivet holes, it is found to be amply strong, with $\frac{9}{16}$-in. metal, to support its proportion of the load, but as the lap must suffer some distortion it would be hard to say just what dependence could be placed upon it.

*Transverse Bulkheads.*—The maximum bending moment to which the transverse girders are subjected is 5 690 ft-tons, as obtained above. The plating required for the static head is $\frac{19}{32}$ in., and the bulkheads are spaced at 8-ft. centers. As the longitudinal frames




TRANSVERSE BULKHEAD

FIG. 10

keep the deck plating rigidly connected as a whole, the entire 96-in. section of skin plating may be considered as forming part of the girder flanges. This width will include part of three transverse strakes, and the weakest section will occur at the butt of one strake. The butts are assumed as double-riveted in the center with rivets of 3-in. pitch, and one strake may be taken at about 40 in., or as including about 22 rivets. Assuming the girder section shown in Fig. 10, then, allowing only the rivet equivalent for the area of the middle strake, and making a proper reduction for rivet holes in the angles,

gives a moment of resistance of 15 220 inch-fourths, as against 15 290 required with the allowed unit stress of 10 000 lb. per sq. in. At 11 ft. on each side of the center, it is desired to cut a central 15 by 30-in. limber hole; and, at a distance of 17 ft., two such holes are needed. The reduced moments of resistance at those points are found to be amply large for the corresponding load moments. The transverse bulkheads are continuous between the side-wall bulkheads, and they are stiffened by the longitudinal frames besides the center and intermediate longitudinal bulkheads.

To determine the deflection of the transverse bulkheads, the general equations for deflection are used.

Moment between $O$ and $A$, $M\ (O - A) = R\,x$,

Moment between $A$ and $B$, $M\ (A - B) = R\,x + \frac{1}{2}\,p\,(x - a)^2$

Moment between $B$ and $C$, $M\ (B - C) = R\,x + \frac{1}{2}\,p\,(x - a)^2 - W\,(x - b)$.

Equating each of these expressions to $E\,I\,\frac{d^2\,w}{d\,x^2}$, integrating, and noting the conditions when $a$, $b$ and $d$ are substituted for $x$, the values of the constants are determined, and an expression for the maximum deflection is obtained. Substituting the proper load and span values in the deflection expression, the theoretical maximum deflection of the transverse bulkheads under the maximum loading is found to be 0.56 in., which is well inside the specified deflection of 1 in 2 000 (0.636 in.).

*Longitudinal Frames.*—A frame spacing of 24 in. was adopted on account of the low unit stresses allowed and the extreme rigidity required. On the assumption that the ship rests on the bilge blocks alone, the direct load on each block placed 4 ft. apart would be 100 tons. As the bilge blocks were specified to be 5 ft. in length and were to rest on 12 by 16-in. yellow pine sills, the loading may be considered as distributed between four longitudinal frames, making a direct concentrated load of 25 tons to each frame. Using the fixed-

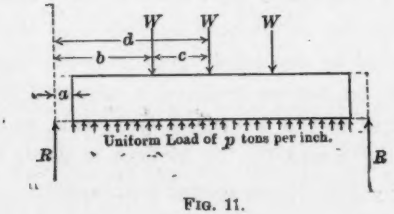



FIG. 11.

beam formula for concentrated loading, and taking the span as the distance between the centers of the rivet groups connecting the top member to the gussets, gives a required moment of resistance of

$$\frac{I}{d} = \frac{25 \times 6 \times 12}{8 \times 4.46} = 50.4.$$

Using a 15-in. by 33-lb. channel for the top chord of the frames, and regarding the effective section of the plating above it as a part of the beam, gives a section composed of the channel, and a 24 by $\frac{19}{32}$-in. cover-plate the area value of which is found by dividing the value of seven $\frac{3}{4}$-in. rivets for single shear by the allowed intensity of stress. This gives a moment of resistance of 48.7. To make up for the uncertainty as to the ends, and to insure rigidity, two knee-braces, composed of one $4\frac{1}{2}$ by 3 by $\frac{7}{16}$-in. angle, are added.

The bottoms of the frames sustain the maximum water pressure only, and, by the use of knee-braces, the span may be broken up into three sections, the longest of which may be taken at 28 in. Regarding each span as a series of fixed-end beams, non-continuous over the braces, gives for the required resistance moment with a 35-ft. head of water:

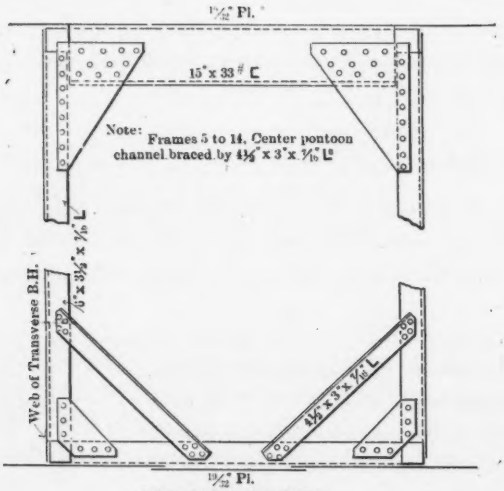
$$\frac{I}{d} = \left[\frac{H}{35} \times \frac{2}{12} \times \frac{2}{28}\right] \div 12 \times 4.46 = 4.$$

Using a 6 by $3\frac{1}{2}$ by $\frac{7}{16}$-in. angle, and considering the rivet equivalent of a 24-in. strip of plating, gives a section having a moment of resistance of 4.2.

The knee-braces carry the reactions from two 28-in. and one 18-in. span, or, $23 \times \frac{H}{35} \times \frac{2}{12} = 3.8$ tons. The braces are set at 45°, and are about 48 in. long, therefore the resultant stress is 5.4 tons. Using a $4\frac{1}{2}$ by 3 by $\frac{7}{16}$-in. angle, with an $\frac{l}{r}$ of 12, and a factor of safety of 4, the safe strength would be 3.5 tons per sq. in.—a total of 11 tons. The end spans of the bottom member would be subjected to a thrust, in addition to the bending, but as in that case the gross sectional area could be depended upon, its capacity is ample. The side angles of the frames are required to transmit the total upward thrust of the water to the transverse bulkheads, and a 6 by $3\frac{1}{2}$ by $\frac{7}{16}$-in. angle, having a capacity for 50 tons, is used, and is attached to the bulkhead by $\frac{3}{4}$-in. rivets spaced 6 in. apart.

The end frames of the pontoons are provided with vertical plate stiffeners, calculated in the usual way to withstand the greatest unbalanced water pressure to which they are exposed. The top chords of the last five frames next the side walls are reduced in size to 12-in. by 25-lb. channels, as they lie beyond the direct ship loads.

*Side-Wall Frames.*—As the side walls form the main longitudinal girders, the framing serves mainly as spreaders, and are placed athwartships, instead of fore and aft. At intervals of 8 ft., and abutting the pontoon transverse bulkheads, is a braced frame for the




ORDINARY FRAMES.

FIG. 12.

purpose of transmitting the pontoon loads. Between the braced frames, and spaced 2 ft. apart, are the ordinary box-frames stiffened by knee-braces and struts. The ordinary side-wall frames are calculated in the same manner as the pontoon frames, with the exception that their members are subjected to an upward thrust as well as to direct bending.

The condition of loading for the braced frames is shown in Fig. 13. The buoyancy of the dock beyond the ship load is the supporting force, and must be transmitted through the side walls, acting as

girders, to the ends of transverse girders. The braces carry this supporting force of 100 tons from the side-wall skin to the connections.

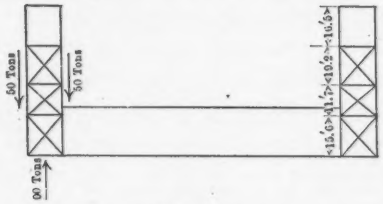



FIG. 13.

Assuming that 100 tons is divided between the verticals, and that each of the six braces takes equal proportions, the vertical component of the brace stress is 8.3 tons, and the resultant brace stress is:

| | | |
|---|---|---|
| For the top pair | 10.5 | tons. |
| For the middle pair | 13 | " |
| For the lower pair | 11.3 | " |

A 5 by 5 by ½-in. angle is adopted, having a safe capacity for 18 tons. The connection between the transverse girder and the side walls is calculated to withstand the shear and bending moment at that point.

*Longitudinal Girders.*—The central longitudinal bulkhead is intercostal between the transverse girders, and, together with Frame No. 1 on each side, forms a compound girder receiving the direct loading from the keel blocks. The span is 8 ft., and the girder is strengthened by an intermediate breathing-plate extending from the center to Frame No. 2 on each side. The keel blocks are 5 ft. long, and the ship load is regarded as distributed over that space. Considering the ship as supported on keel blocks alone, the load per span of 8 ft. is 400 tons, to be carried between transverse girders. The section of girder adopted and sketch plan showing the area of rivets counted is shown in Fig. 14.

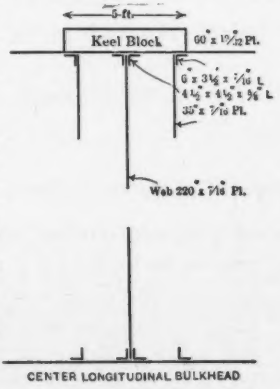



FIG. 14.

The resistance moment of the section is ample, of course, for the bending. To transmit the direct load into the girder, the rivets are distributed as follows:

| | Double shear. | Equivalent single shear. |
|---|---|---|
| Center bulkhead | 29 | 46 |
| Transverse bulkhead | 16 | 26 |
| Breathing-plate | 10 | 16 |
| Two brackets | | 20 |
| Four curtain-plates | | 52 |
| Total single shear | | 160 |

$400 \div 160 = 2.5$ tons per rivet in single shear, or 12 800 lb. per sq. in.

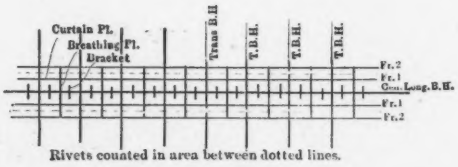



FIG. 15.

This result is deemed satisfactory when it is considered that the assumption that the whole ship rests on the keel blocks alone is one which can never materialize.

The side and intermediate transverse bulkheads are made up, like the center, of $\frac{7}{16}$-in. plate and $4\frac{1}{2}$ by $4\frac{1}{2}$ by $\frac{5}{8}$-in. angles. The intermediates are strengthened by a channel rib placed horizontally at about one-third the depth to provide for unequal water pressure when listing the dock.

*Other Hull Details.*—All non-watertight bulkheads have 12 by 30-in. openings, to allow the passage of water, and are provided with small limber holes near the top and bottom flanges for air drainage.

All connection details are computed in the regular manner, care being taken to avoid direct pull on the rivet heads.

The bending moment at the joint between the pontoons, for both ship and dock loads, may be taken at 120 000 ft-tons. A section resistance moment of 323 000 is therefore required. Using the con-

nections shown in Fig. 16, consisting of seven elements each comprising forty-four 2-in. bolts, and considering the overhang with bolts alone, a resistance moment of 730 000 inch-thirds is obtained. Using the overhang section and the section of the ¾-in. diaphragm plate, a moment of 613 400 inch-thirds gives nearly twice the required strength. In addition to the vertical connections, a row of 1½-in. bolts connects the end pontoon decks with the four bottom edges of the overhangs, and there are 96 bolts in each row.

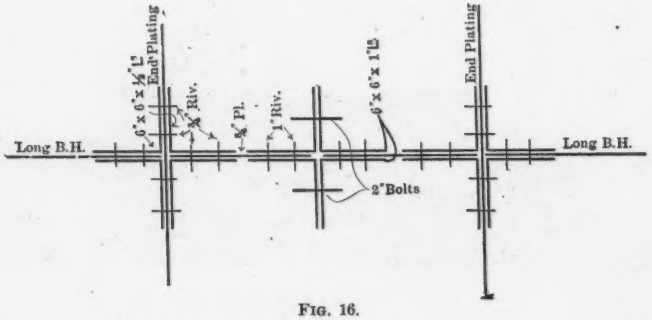



FIG. 16.

The strength of the overhang section when unsupported by the end pontoon may be determined by the following assumed weights and their location:

| | | | | | |
|---|---|---|---|---|---|
| Weight of overhang..... | 320 | tons, | arm | 40 | ft. |
| " " quarters..... | 11 | " | " | 44 | " |
| " " bridge..... | 8 | " | " | 80 | " |
| " " live load..... | 20 | " | " | 40 | " |

Moment = 14 724 ft-tons, which, divided by the resistance, 102 346, gives 1.16 tons per sq. in. stress.

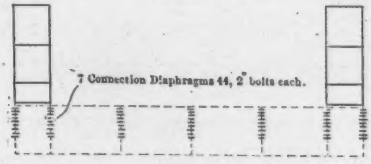



FIG. 17.

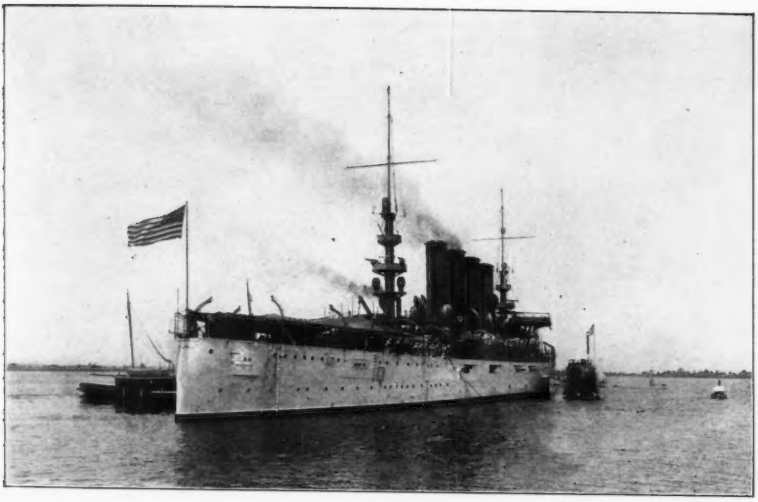


FIG. 1.—U. S. S. *Colorado* ENTERING DOCK.

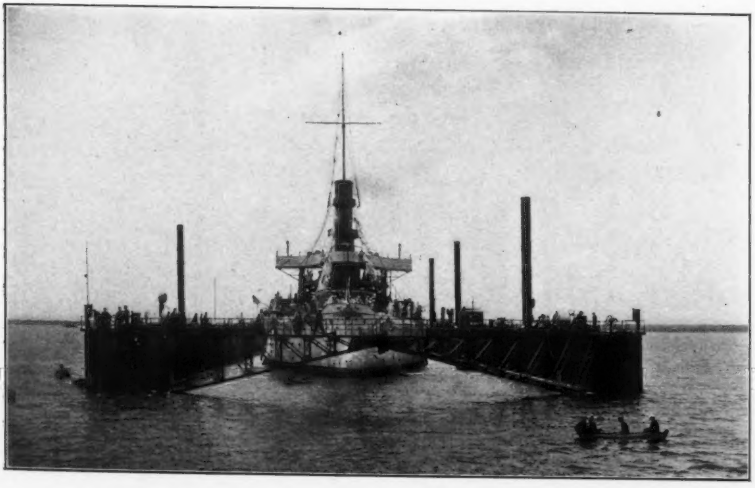


FIG. 2.—U. S. S. *Iowa* CENTERED IN DOCK; READY TO BEGIN PUMPING.

*Strength of the Dock as a Whole.*—The moment of inertia of the dock, according to the above preliminary design, was taken at different sections as follows:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Center | | | | | | 384 681 832 | inch-fourths. | |
| (*a*) | 31.5 | ft. | from | center | .... | 379 382 072 | " | " |
| (*b*) | 39.6 | " | " | " | .... | 371 764 400 | " | " |
| (*c*) | 49.5 | " | " | " | .... | 370 011 050 | " | " |
| (*d*) | 56.25 | " | " | " | .... | 368 218 500 | " | " |
| (*e*) | 70. | " | " | " | .... | 348 510 714 | " | " |
| (*f*) | 110. | " | " | " | .... | 321 140 084 | " | " |
| (*g*) | 131.17 | " | " | " | .... | 313 661 487 | " | " |

(The center of gravity of the center section is 371.2 in. from the center of the bottom plating.)

A second bending-moment diagram was then drawn, using the actual load curve of a 16 000-ton battleship. A comparison of the required resistance with that provided above led to the doubling of certain of the tower deck plates, the addition of a channel stringer and a slight increase in the thickness of the upper side-wall plating. The final moments of inertia corresponding to the above sections are as follows:

| | | |
|---|---|---|
| At center | | 384 681 832 |
| Section | *a* | 379 382 072 |
| " | *b* | 375 872 940 |
| " | *c* | 374 188 880 |
| " | *d* | 372 456 168 |
| " | *e* | 353 061 010 |
| " | *f* | 326 317 300 |
| " | *g* | 322 667 487 |

A curve was then drawn, with ordinates obtained by dividing the bending moment at various sections by the corresponding moment of inertia. Treating this curve, called the "$\frac{M}{I}$" curve, as a load curve, the bending moment obtained from it indicates the deflection of the dock. The calculation was made graphically, and resulted in a maximum estimated deflection of 2.9 in. at the center, slightly less than 3 in. allowed by the specification.

In investigations of the dock's strength on the crest or in the hollow of a wave of height equal to one-twentieth of the span, no bending moment can be obtained exceeding 200 000 ft-tons, which is small in comparison with that given by the ship. In self-docking the center pontoon, each end rests on an 80-ft. deck length of end pontoon, and considering the dock as a beam of span equal to the distance between the center of bearings, a bending moment of 231 000 ft-tons is obtained. This, however, is on the assumption that the weight of the center pontoon, 7 750 tons, is distributed over the span, a more severe condition than that which actually occurs as the overhangs tend to reduce the moment.

STABILITY.

Referring to Fig. 18:

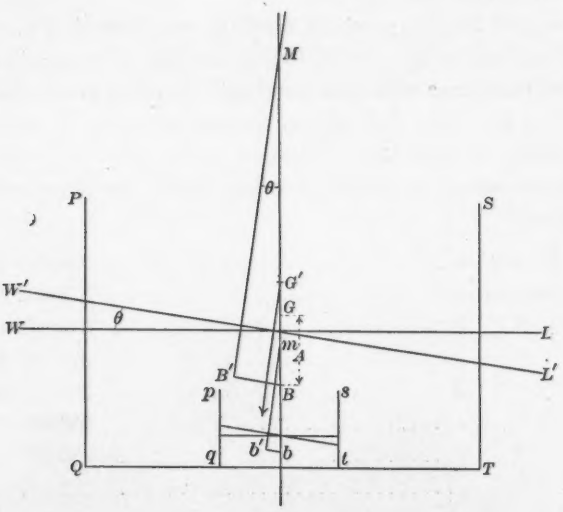



FIG. 18.

*PQST* is a floating vessel;
*pqst* is an interior compartment, partly filled with water;
*WL* and *W′L′* are water lines, before and after inclination;
*wl* and *w′l′* are interior water surfaces, before and after inclination;
*B* and *B′* are centers of buoyancy, before and after inclination;

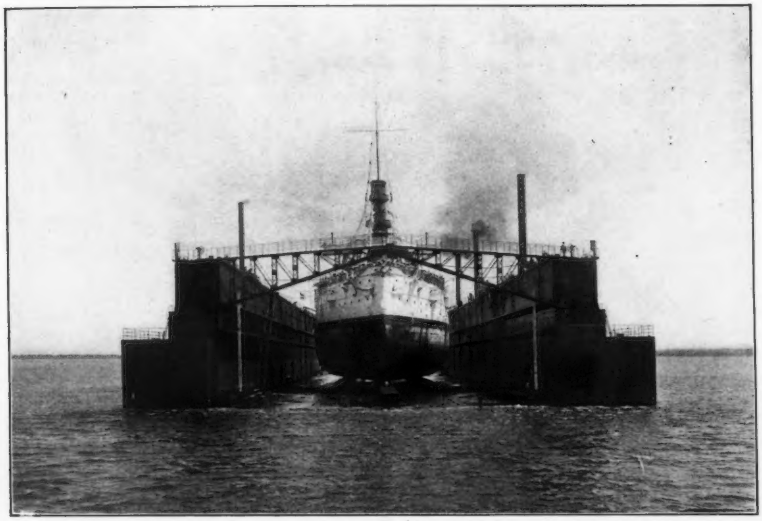


FIG. 1.—U. S. S. *Iowa* IN DOCK, WITH PONTOON DECK OF DOCK AWASH.

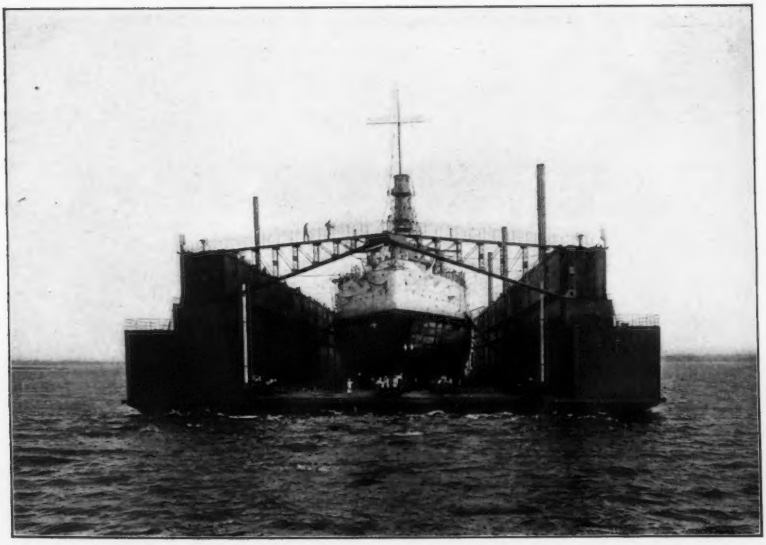


FIG. 2.—U. S. S. *Iowa* IN DOCK. DOCK AT 4½ FT. FREEBOARD.

$b$ and $b'$ are centers of gravity of interior water carenes, before and after inclination;

$D$ is the displacement of the dock, in tons;

$d$ is the weight of the contained water in tons;

$V$ is the value of the displacement of the dock, in cubic feet = 35 $D$;

$v$ is the value of the contained water, in cubic feet = 35 $d$;

$I$ is the transverse moment of inertia of the water planes;

$i$ is the transverse moment of inertia of the contained water surface.

The metacentric radius, called $R$, is the distance, $B\ M$; and the metacentric height, called $H$, is the distance, $G\ M = R - B\ C$, or $R - a$. By a simple process, it is easily proven that $R = \frac{I}{V}$ when $I$ is the transverse moment of inertia of the water plane and $V$ is the volume of displacement. The same expression can be used for the water in a contained compartment of a floating body, in which case the center of buoyancy and the center of gravity are identical.

When a vessel rolls, the contained water moves from side to side and acts in all respects as if it were suspended from a point which corresponds with the metacenter, $M$, of an empty vessel. The effect of the contained water, therefore, may be said to raise the center of gravity a distance, $B\ M$, in Fig. 18, which would raise the center of gravity of the whole vessel a distance

$$G\ G' = \frac{d \times b\ m}{D},$$

in which $d$ = the weight of the contained water, in tons; and $D$ = the displacement of the dock, in tons. Assuming 35 cu. ft. of sea water = 1 ton,

$$D = \frac{V}{35} \text{ and } d = \frac{v}{35},$$

therefore,

$$G\ G' = \frac{v \times b\ m}{V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

But, considering the interior compartment as an exterior carene,

$$b\ m = \frac{i}{v},$$

therefore,

$$G\ G' = \frac{v}{V} \times \frac{i}{v} = \frac{i}{V} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The moment of stability, therefore, is,

$$D \cdot G' M \sin. \theta = D (G M - G G') \sin. \theta$$
$$= D \left(G M - \frac{i}{V}\right) \sin. \theta,$$

$D \cdot G' M \sin. \theta$ = new stability moment = $M'$

$$= D \left(H - \frac{i}{V}\right) \sin. \theta \ldots\ldots\ldots (3)$$

Therefore the effect of the contained water is to reduce the metacentric height by $\frac{i}{V}$; or $\Sigma \frac{i}{V}$, should there be more than one compartment.

$$B M = R = \frac{I}{V}$$

$$H = R - A = \frac{I}{V} - A$$

$$H - \frac{i}{V} = H' = \frac{I}{V} - A - \frac{i}{V}$$

$$H' = \frac{I - A V - i}{V} \ldots\ldots\ldots\ldots (4)$$

Or, when there are more than one of such interior compartments,

$$H' = \frac{I - A V - \Sigma i}{V}.$$

From Equation 3,

$$M' = D \cdot H' \sin. \theta = \frac{V}{35} \left(\frac{I - A V - \Sigma i}{V}\right) \sin. \theta.$$

$$M' = \frac{\sin. \theta}{35} (I - A V - \Sigma i) \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

For $\theta = 1°$,

$$M' = \frac{I - A V - \Sigma i}{35} \times 0.0175 \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The stability curves shown in Fig. 19 are constructed on Equations 4, 5, and 6. When the ship is on the dock its own stability must be taken into consideration, and the $I$ of the above expressions becomes $I + I_1$.

It will be seen from an inspection of Fig. 19 that there are critical points at the pontoon-deck level and at the top of the blocking before the water plane cuts the ship.

In determining the heeling effect of wind pressure, the moment of the wind, taken at 30 lb. per sq. ft. over one side wall into the

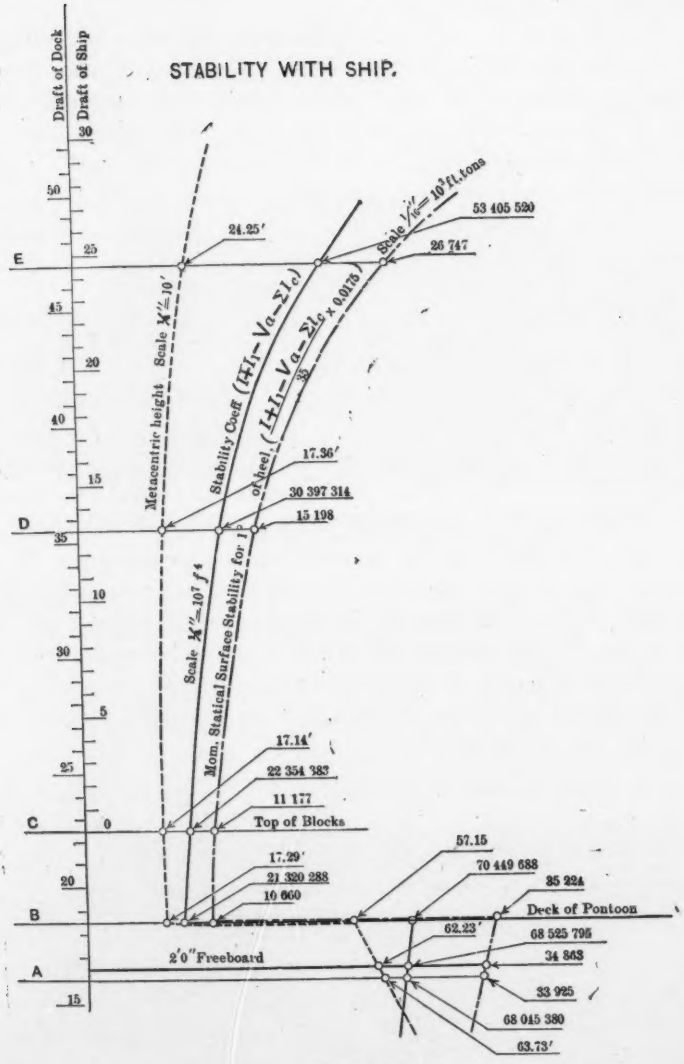

STABILITY WITH SHIP.
Draft of Dock
Draft of Ship
30
50
25
45
20
40
15
35
10
30
5
25
0
20
15
E
D
C
B
A
24.25′
26 747
53 405 520
Scale 1/16″ = 10⁶ ft. tons
Metacentric height Scale X″ = 10′
Stability Coeff (ΣI₁ − Va − ΣIc)
of heel (ΣI₁ − Va − ΣIc × 0.0175)
35
17.36′
30 397 314
15 198
Mom. Statical Surface Stability for 1°
Scale X″ = 10⁷ f t
17.14′
22 354 383
11 177
Top of Blocks
57.15
70 449 688
85 224
Deck of Pontoon
17.29′
21 320 288
10 660
62.23′
68 525 795
34 863
2′0″ Freeboard
33 925
68 015 380
63.73′

FIG. 19.

distance between the line of its action and the intersection of new and old water lines, is equated to the righting moment and solved for the angle of inclination.

Calculations for stability were made for the following positions: When the dock has a freeboard of 2 ft. 6 in.; when the deck is flush with the surface of the water; and at points where the drafts are 4 ft., 17 ft. and 30 ft. 6 in. above the deck. The curves shown on Fig. 19 are based on these calculations, and give the righting properties of the dock, with the lifted ship, at all positions. Similar curves were also drawn for the dock as a whole and for each section alone, with and without ship loading, and for self-docking operations.

## Machinery.

The specifications require the dock to lift a 16 000-ton battleship to a freeboard of 2 ft. in 4 hours. The quantity of water to be removed is 34 700 tons in 4 hours. Three main pumping elements were decided upon, all of which were to be placed on the port side. The pumps were to be of the vertical-shaft centrifugal type and to rest directly upon a main drain running throughout the length of the side wall, with branches to each pumping compartment. Each pump, therefore, was required to lift 1 686 cu. ft. of water per min. against a 35-ft. head. Assuming a velocity of 10 ft. per sec., the area of the main drain required would be 2.8 sq. ft.; therefore a 24-in. pipe was used, giving a velocity of 9 ft. per sec. The dimensions of the pumps for the preliminary design, with a maximum head of 40 ft., were determined as follows:

| | |
|---|---|
| Outside diameter of wheel..... | 4 ft. 10 in. |
| Inside " " " ..... | 2 ft. 3 in. |
| Revolutions per minute..... | 225 |
| Diameter of suction and discharge.... | 24 in. |

*Engines.*—The theoretic power required with a head of 40 ft. would be 130 h. p., and, assuming a hydraulic efficiency of 58%, the actual engine power to be provided for each of the three pumping elements would be 225 h. p. Horizontal, compound, non-condensing engines, 14½ by 25 by 14-in.; with cylinders set at an angle of 135° were adopted. The angle between the cylinders gives a slightly unbalanced turning moment on the shaft, but the disadvantage is of small

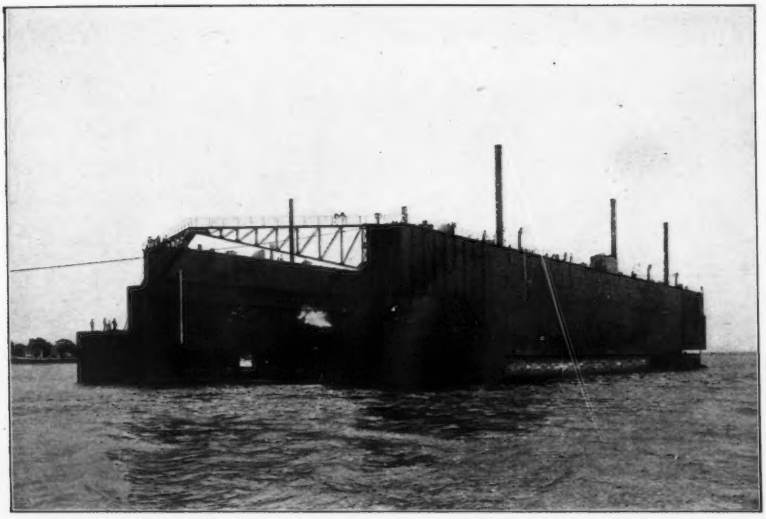


FIG. 1.—SELF-DOCKING: STERN PONTOON SUBMERGED AND DRAWN UNDER CENTER PONTOON; BOW PONTOON IN POSITION FOR SIMILAR OPERATION.

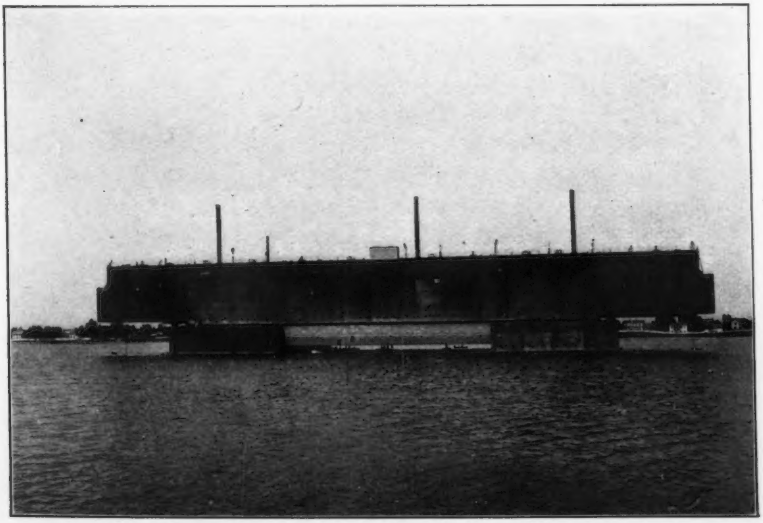


FIG. 2.—SELF-DOCKING: SIDE VIEW, SHOWING CENTER PONTOON DOCKED.

account, and, by placing the engines as nearly as possible in the direction of the length of the dock, vibration was reduced to a minimum. The pumps and engines were designed and manufactured by the Morris Machine Works, of Baldwinsville, N. Y.

*Boilers.*—Babcock and Wilcox, marine type, water-tube boilers were adopted, each of 1 750 sq. ft. heating surface, 46 sq. ft. grate surface, and were designed to work at 150 lb. steam pressure.

*Auxiliary Machinery.*—An air compressor having a capacity of 527 cu. ft. per min. was installed on the port side. On the starboard side was installed a small machine shop, with lathe, drill, shaper, etc., an electric generating set for lighting the dock, and an evaporator, fire pump, etc., together with a donkey boiler for generating the necessary steam.

## Construction.

The dock was constructed by the Maryland Steel Company, at its works at Sparrow's Point, Md. A basin was excavated in the foreshore and closed by a coffer-dam. A sufficient number of spruce piles were driven to support the estimated weight of the dock, allowing 6 tons to the pile. A 6-in. centrifugal pump, electrically driven, was operated continually for drainage. The structural material was rolled at the works of the Pennsylvania Steel Company, at Steelton, Pa., and of the Central Iron and Steel Company, at Harrisburg, Pa., and was milled at Sparrow's Point. As the dock was designed to avoid all curved work, and as the type of structure renders possible the use of similar members, the multiple punch was available in machining all the plating and bulkheads, while all frames were assembled and riveted by yoke machines in the yard.

Erection was carried on in a simple and rapid manner. A trestle was built out into the basin at the same level as the pontoon decks. Two 10-ton traveling cranes, with arm height and reach sufficient to handle weights at any part of the completed structure, were erected on these trestles. As the first bay of the end pontoon was erected, the trestle stringers with crane tracks were extended over the transverse bulkheads. As the work progressed, the track was extended throughout the length of the dock.

All detailed plans were prepared in the course of construction, and, as the supervising engineer was permanently stationed at the

works, all plans were checked and approved with the least possible delay.

The selection of a protective coating for the dock was made the subject of careful study. Samples of a number of the best known paints on the market, exclusive of the oxide paints, were applied to test-plates and subjected to different conditions. Three plates were coated with each sample, one was exposed to the weather at the company's works, a second was suspended half in air and half in water, and a third was submerged in the water of Chesapeake Bay. The tests extended over a period of 2 years, during the construction of the dock, and resulted in the choice of a mixture of red lead, white zinc and linseed oil in the following proportions: 100 lb. of red lead, 15 lb. of zinc ground in oil, and 15 gal. of linseed oil. It is only fair to state that in these tests a graphite paint manufactured in Detroit showed as good results as the red lead, but was not used because of the lack of available data bearing on its behavior in salt water.

As the pontoons have more or less water in their bottoms at all times, except when self-docked, it was very necessary to provide adequate protection for their floors. Experiments with Bitumastic Enamel led to its application to the whole of the interior floors and to all vertical bulkheads, braces, etc., to a height of 12 in. The process of applying this mixture consists in a careful cleaning and drying of the metal, one coating of a solution the function of which is to provide a surface to which the enamel will adhere, and a final heavy coating of the enamel, from $\frac{1}{16}$ to $\frac{1}{8}$ in. in thickness, applied hot.

Great care was taken to rid the hull plating of mill scale. The specification provided that all loose scale should be removed by hammering, scraping, and brushing with wire brushes, and to make its removal easier and surer, no paint was applied until a short time before launching. Nearly all the material, therefore, was exposed to the weather in the yard for periods ranging from 12 to 24 months. The existence of mill scale on the completed structure has such an important bearing on the subject of corrosion that the additional expense entailed by pickling would be a good investment in the way of insurance, and it is recommended that specifications for future docks include this requirement. It was also noticed that, in the process of weathering, the mill scale, where covered with paint, ad-

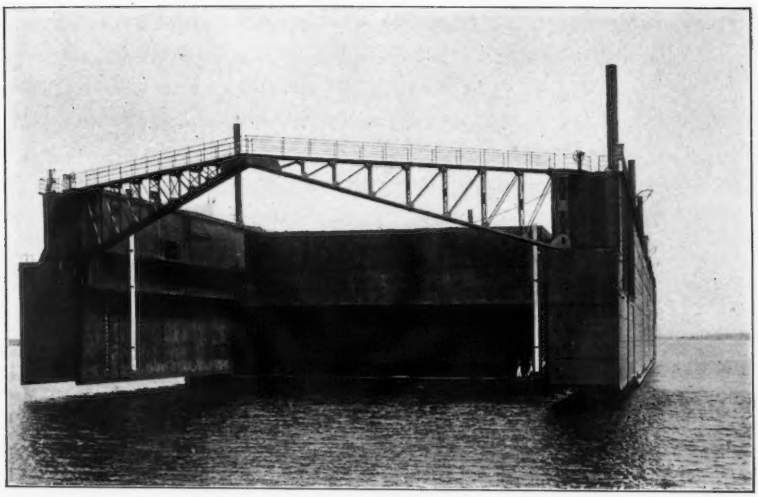


FIG. 1.—SELF-DOCKING: END PONTOONS DOCKED.

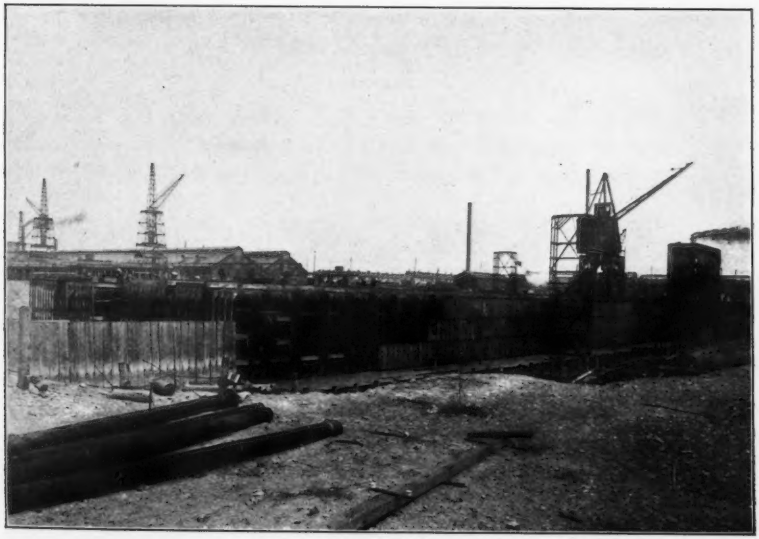


FIG. 2.—VIEW OF DOCK, MARCH 16TH, 1904, SHOWING BOTTOM PLATING IN PLACE ON BLOCKING IN BUILDING BASIN, MAIN PONTOON FRAMING, ETC.

Non

hered closely and could not be removed without the use of hammer and chisel. This scale, of course, will come off in time, and for this reason the requirement, that all contact surfaces be given one coat of paint before assembling, should be limited, so as to apply to rolled shapes only.

The contract for the dock was awarded on April 20th, 1903, and the first shipment of plates was received at Sparrow's Point on July 17th. The first bottom plate was laid on the blocking on September 23d, 1903, and the dock was launched on June 10th, 1905. The official ship docking and self-docking tests were held in the mouth of the Patuxent River, where the dock was towed immediately after the launching. A very complete description of the official tests by Civil Engineer A. C. Cunningham, U. S. Navy, Member of the Testing Board, was published in the *Journal* of the American Society of Naval Engineers,* and as the information contained therein may be desirable for purposes of discussion, it is deemed expedient to quote directly from that excellent paper.

"The U. S. S. *Colorado* was docked on June 23, 1905, having a displacement of 13 300 tons at that time. The main and docking keel blocks were all set at the same height. In this preliminary test no effort was made to secure speed, and one-half hour was used in making flushing and fire connections. The elapsed time from when the ship landed on the blocks until the keel came out of water was two hours and sixteen minutes. Pumping was continued until the dock had a uniform freeboard of two and one-half feet, only enough excess of water being retained in the side walls and end compartments to give the necessary trim. The *Colorado* was carried on the dock about twenty-four hours without changing the water ballast. When the dock had reached a freeboard of two and one-half feet with the *Colorado*, the deflection on the main keel line in the five hundred feet of length of the dock was about one-quarter of an inch; after about twenty-four hours the deflection in five hundred feet increased to about one and one-sixteenth inches. After undocking the *Colorado* the dock was found to have practically straightened without retaining any set.

"After the undocking of the *Colorado*, deflection observations were continued for three days, and variations in deflections with the dock unloaded, due to temperature changes, of seven-eighths of an inch were noted.

"The battleship *Iowa* was docked on June 27, 1905, for a record test, having a displacement of 11 600 tons at the time, and was car-

* Vol. XVII, No. 3.

works, all plans were checked and approved with the least possible delay.

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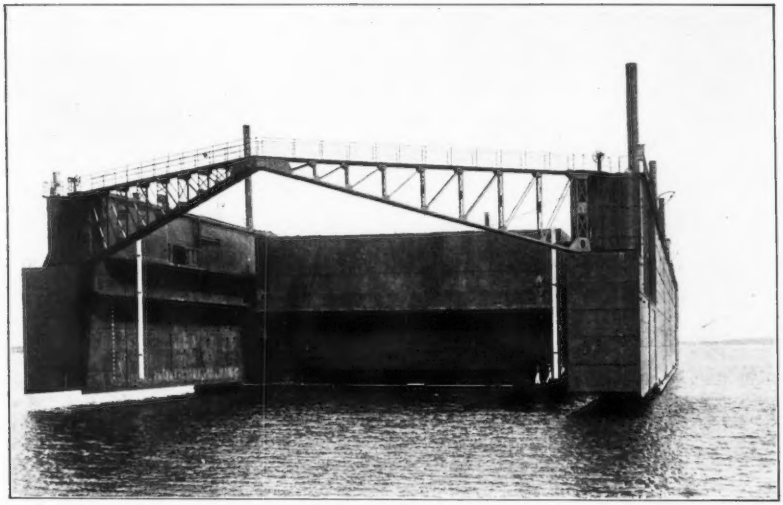


FIG. 1.—SELF-DOCKING: END PONTOONS DOCKED.

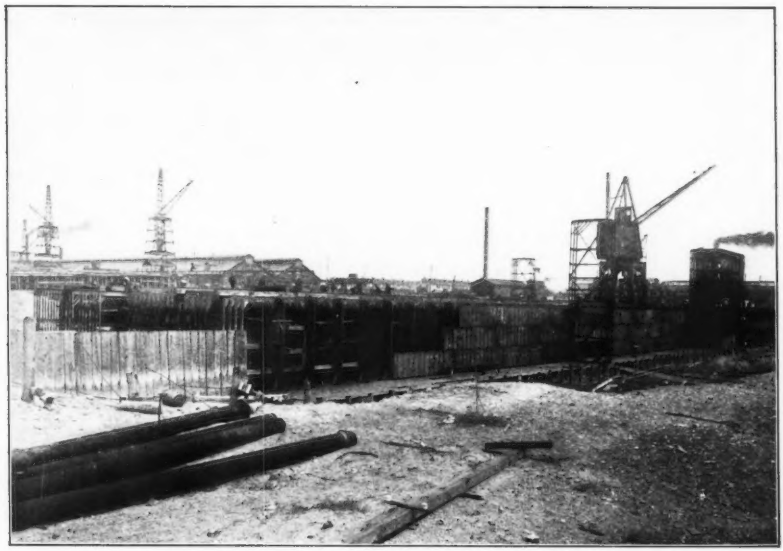


FIG. 2.—VIEW OF DOCK, MARCH 16TH, 1904, SHOWING BOTTOM PLATING IN PLACE ON BLOCKING IN BUILDING BASIN, MAIN PONTOON FRAMING, ETC.

hered closely and could not be removed without the use of hammer and chisel. This scale, of course, will come off in time, and for this reason the requirement, that all contact surfaces be given one coat of paint before assembling, should be limited, so as to apply to rolled shapes only.

The contract for the dock was awarded on April 20th, 1903, and the first shipment of plates was received at Sparrow's Point on July 17th. The first bottom plate was laid on the blocking on September 23d, 1903, and the dock was launched on June 10th, 1905. The official ship docking and self-docking tests were held in the mouth of the Patuxent River, where the dock was towed immediately after the launching. A very complete description of the official tests by Civil Engineer A. C. Cunningham, U. S. Navy, Member of the Testing Board, was published in the *Journal* of the American Society of Naval Engineers,* and as the information contained therein may be desirable for purposes of discussion, it is deemed expedient to quote directly from that excellent paper.

"The U. S. S. *Colorado* was docked on June 23, 1905, having a displacement of 13 300 tons at that time. The main and docking keel blocks were all set at the same height. In this preliminary test no effort was made to secure speed, and one-half hour was used in making flushing and fire connections. The elapsed time from when the ship landed on the blocks until the keel came out of water was two hours and sixteen minutes. Pumping was continued until the dock had a uniform freeboard of two and one-half feet, only enough excess of water being retained in the side walls and end compartments to give the necessary trim. The *Colorado* was carried on the dock about twenty-four hours without changing the water ballast. When the dock had reached a freeboard of two and one-half feet with the *Colorado*, the deflection on the main keel line in the five hundred feet of length of the dock was about one-quarter of an inch; after about twenty-four hours the deflection in five hundred feet increased to about one and one-sixteenth inches. After undocking the *Colorado* the dock was found to have practically straightened without retaining any set.

"After the undocking of the *Colorado*, deflection observations were continued for three days, and variations in deflections with the dock unloaded, due to temperature changes, of seven-eighths of an inch were noted.

"The battleship *Iowa* was docked on June 27, 1905, for a record test, having a displacement of 11 600 tons at the time, and was car-

* Vol. XVII, No. 3.

ried on the dock for forty-eight hours. The specifications required that a 16 000-ton ship should be raised in four hours from the time the ship took the blocks until the keel was out of water. For the equivalent of a 16 000-ton ship the dock was pumped to a freeboard of four and one-half feet. From the time the *Iowa* took the blocks until the keel was out of water was one hour and thirty-seven minutes; to the time the dock had a freeboard of four and one-half feet, two hours and forty-two minutes. During the docking of the *Iowa* one of the three pumping engines was out of commission for forty-two minutes with a slipped eccentric, so that the actual time of operation of the dock is about half that allowed by the specification.

"The *Iowa* was docked by uniform pumping, as in the case of the *Colorado*, and carried for forty-eight hours without change of water ballast in the dock. The specification required that when a ship had been docked by uniform pumping until the dock had a freeboard of two feet the deflection in the entire 500 feet of length of the dock should not exceed three inches. When the dock reached a freeboard of four and a half feet with the *Iowa*, the deflection was about two inches. During the first twenty-four hours, the dock remaining uniformly pumped, the deflection increased to four inches in the 500 feet, and during the second twenty-four hours showed a recovery to three and three-eighths inches.

"Immediately following the undocking of the *Iowa* the dock was pumped up to the same depth of water in the compartments as when the ship was docked, which gave a freeboard of nine feet and six inches, and it was found that the dock had a hog of one inch. During the night this hog disappeared, and early the next morning was a half inch sag. The greatest deflection in the bearing length of the *Iowa* while carried on the dock was about one and three-quarter inches. The deflection observations indicate that there was no permanent set caused by the docking, and that temperature variations may cause considerable hog or sag.

"After the undocking of the *Colorado* the main and docking keel blocks were found to be uniformly indented about one-sixteenth of an inch with no crushing. No change was made in the blocks for the *Iowa*, and after undocking she was found to have rested even more easily than the *Colorado*."

During July the pontoons were successfully self-docked, and full particulars of this operation, by the writer, have also appeared in the *Journal* of the American Society of Naval Engineers.* The total time consumed in the self-docking tests, exclusive of time spent on the blocks, was about 15 days, and it would seem probable that the time required for future self-dockings could be reduced to from 10 to 11 working days.

* Vol. XVII, No. 3.



FIG. 1.—VIEW OF DOCK, MAY 1ST, 1904; BOTTOM PLATING AND BOW PONTOON IN POSITION.

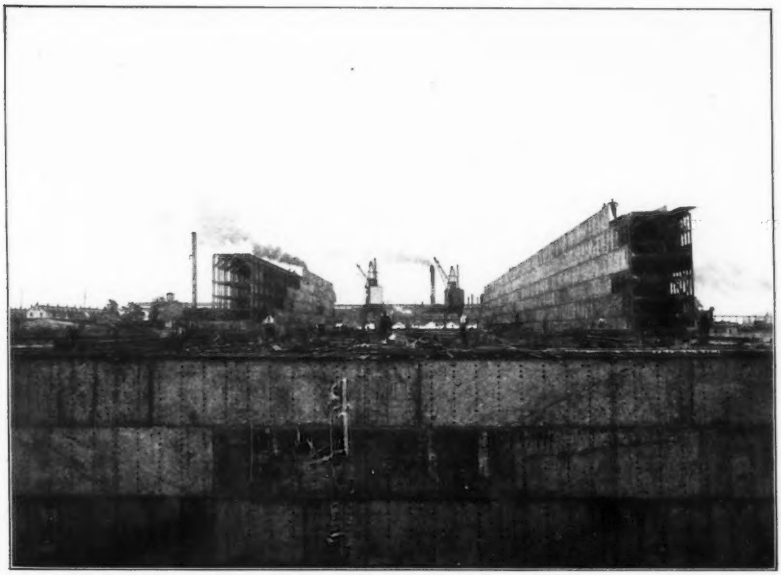


FIG. 2.—VIEW OF DOCK, AUGUST 1ST, 1904, SHOWING SKIN PLATING OF PONTOONS AND SIDE WALLS.

The self-docking was in every way a success, but it may be of interest to call attention to one point which, while not affecting the safety of the structure, may yet be considered a defect of design. Preliminary to docking the center pontoon, it was necessary to disconnect the end pontoons and sink them to sufficient draft to allow them to be drawn under the center section. During the process of sinking the bow section, it was observed that after the pontoon deck was below the surface of the water it was very difficult to maintain longitudinal trim. First the forward end would sink more rapidly and when this was checked by the valves the after end would forge

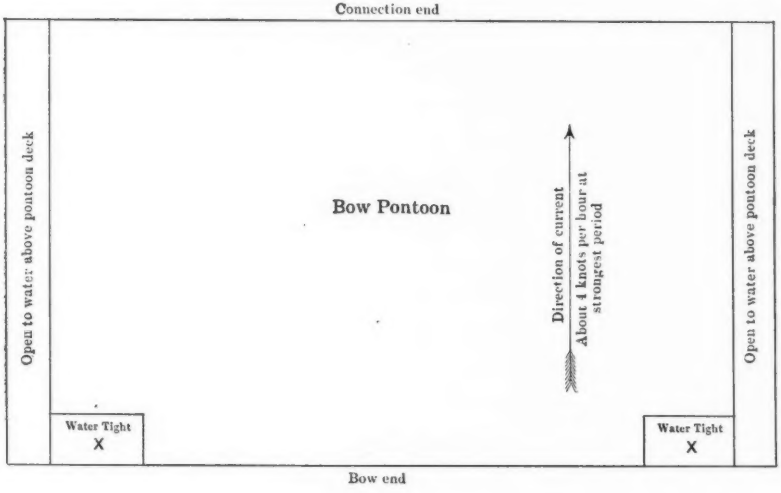



FIG. 20.

ahead. This surging was not alarming, and would bring up within 3 or 4 ft. either way. The natural explanation of this action would seem to lie in the lack of symmetry of the horizontal section. When the deck is once covered with water, the flotation of the pontoon having been destroyed, the excess flotation at $X$ (Fig. 20), where the side walls come around the end, hold that end up while the other tends to go down. The opposite result was probably due to the momentum acquired by the bow when the forward valves were closed. It should be observed, however, that the stern pontoon did not surge, so that the explanation offered may not be the correct one.

It is possible that the surging experienced in submerging the Algiers dock may be explained by its pointed end pontoons and short side walls, and if this is true it would indicate that rectangular pontoons and full-length side walls are the best for stability during submergence.

The *Dewey* has proven a complete success in every way. It has performed everything that was required of it, both as regards the docking of ships and the raising of its own pontoons; and it should be said here that the highly satisfactory results attained were largely due to the very evident desire on the part of the contractors to reach the highest mark in dry-dock construction, and the structure must stand as a monument to the executive ability and skill of their engineers.

Any prediction as to the lines along which future development in floating dock construction will take place can have only the value of a personal opinion, but it would seem, from the tendency of recent designs and the demand for a rigid structure for naval purposes, that the solid-trough dock will again come into favor. It is, without doubt, the ideal dock, and it would be generally adopted for naval use if it could be self-docked. It is possible that a designer may invent a plan or device for self-docking the solid dock, and, when this is an accomplished fact, it would seem that future advance must be confined to matters affecting the lifting capacity, structural strength, and general convenience.

The choice of power for operating the machinery is governed by special circumstances, but the desirability of furnishing light and power to ships in dock may influence the more general use of electricity in the future. When located at repair yards the current could be supplied from power-houses ashore, and the dock could be provided with a generating plant for independent operation, as in the case of the Pensacola (formerly Havana) dock.

To facilitate towing, the pontoons might be given a scow-shaped bow and stern, and, though involving considerable additional expense, the corners might be slightly rounded without interfering to any great extent with the stability. Self-propelled docks have been proposed, and such a dock is practical, but it is doubtful if there is yet a sufficient demand to warrant their serious consideration.

It should be pointed out, in explanation of the incompleteness of this paper, that it is intended merely as a basis for a helpful discussion of a subject which must be of interest to all who are in any way connected with modern ships; and, if it should succeed in eliciting such discussion, its preparation will have been in a measure justified, despite its numerous and obvious shortcomings.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## RECENT PRACTICE IN HYDRAULIC-FILL DAM CONSTRUCTION.

By James D. Schuyler, M. Am. Soc. C. E.

To be Presented December 19th, 1906.

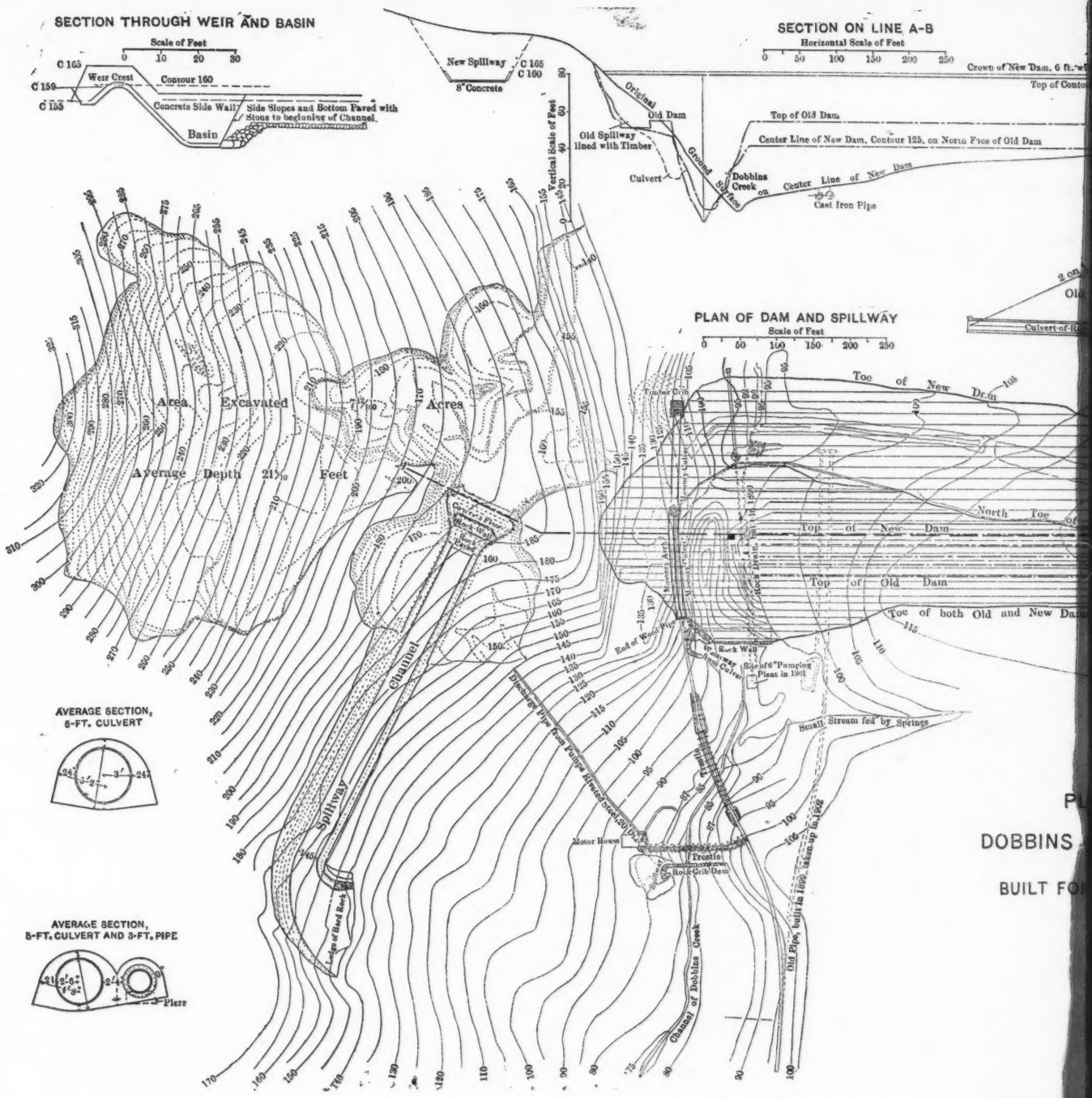
The widespread interest which is being taken by engineers throughout the world in the methods used in Western America in the construction of dams for water storage, by the agency of water for loosening, conveying, assorting, distributing, depositing and consolidating the materials, has prompted the writer to prepare an account of his experience in this novel class of construction, and to gather such data as were obtainable from the experience of others.

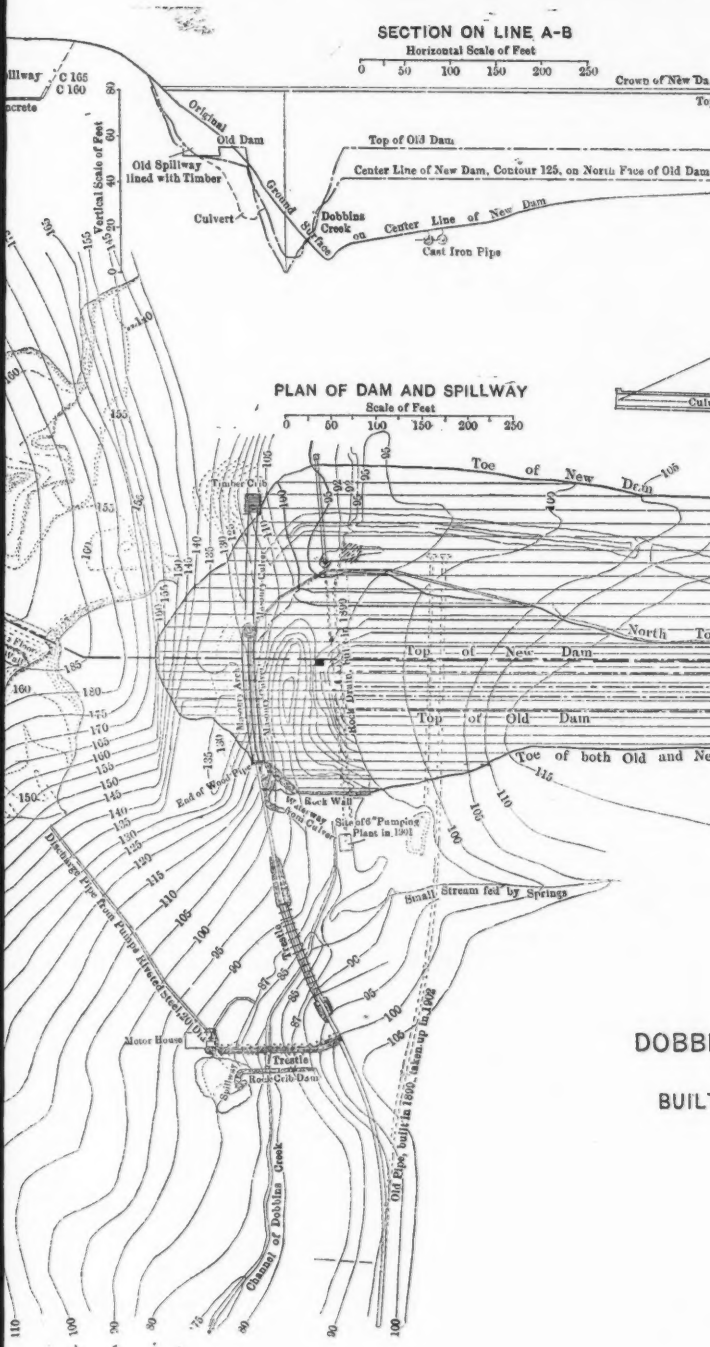
The principles primarily involved in the design of any earth dam are the following:

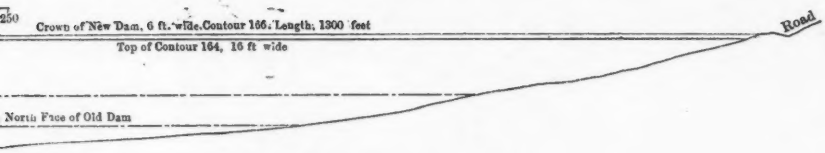
*First.*—It must be founded on an impermeable foundation, and form a water-tight connection with the rock or clay bed on which it rests.

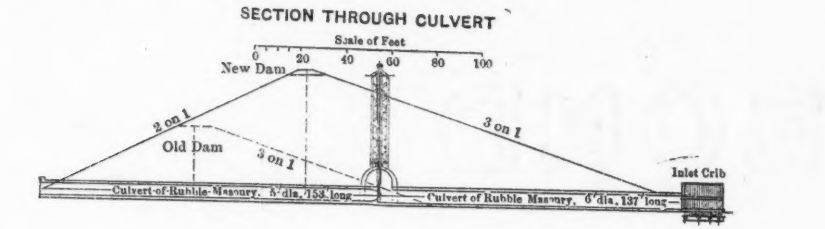
*Second.*—It must be practically impervious to water, in the whole, or at least in a goodly portion, of its entire cross-section.

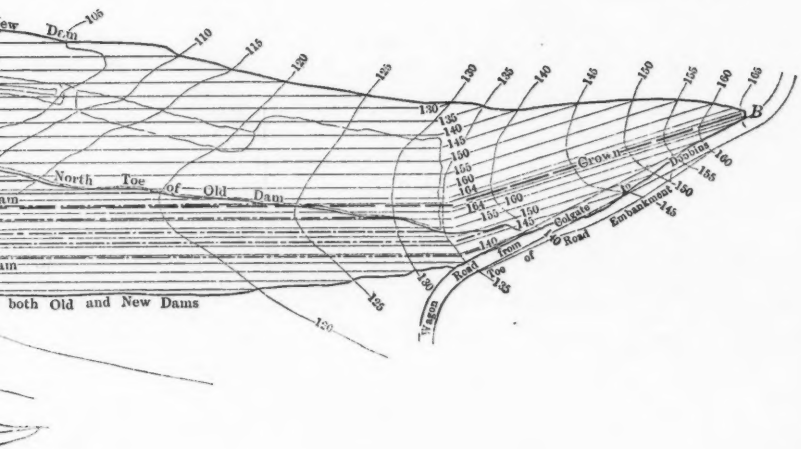
Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.


SECTION THROUGH WEIR AND BASIN
Scale of Feet
0 10 20 30
C 165
C 150
C 155
Weir Crest
Contour 160
Concrete Side Wall
Side Slopes and Bottom Paved with Stone to beginning of Channel
Basin
New Spillway
C 165
C 160
8" Concrete
SECTION ON LINE A-B
Horizontal Scale of Feet
0 50 100 150 200 250
Vertical Scale of Feet
Crown of New Dam, 6 ft. w
Top of Conto
Original Ground Surface
Old Dam
Top of Old Dam
Old Spillway lined with Timber
Center Line of New Dam, Contour 125, on North Face of Old Dam
Culvert
Dobbins Creek
Center Line of New Dam
Cast Iron Pipe
PLAN OF DAM AND SPILLWAY
Scale of Feet
0 50 100 150 200 250
Area Excavated 7 1/10 Acres
Average Depth 21 1/10 Feet
Toe of New Dam
North Toe of
Top of New Dam
Top of Old Dam
Toe of both Old and New Dam
Timber Cribs
Masonry Culvert
Rock Fill 1909
Rock Fill 1908
Rock Wall
Rock Paved
Channel
Spillway
Ledge of Hard Rock
End of Wood Pile
Rock Wall
Stone Culvert
Site of 6" Pumping Plant in 1901
Small Stream fed by Springs
Discharge Pipe from Pumps Riveted Steel 30" Dia.
Motor House
Trestle
Rock Crib Dam
Old Pipe, built in 1900, taken up in 1908
Channel of Dobbins Creek
AVERAGE SECTION, 6-FT. CULVERT
AVERAGE SECTION, 5-FT. CULVERT AND 3-FT. PIPE
Piers
PL
DOBBINS
BUILT FO


SECTION ON LINE A-B
Horizontal Scale of Feet
0 50 100 150 200 250
Crown of New Da
To
Original
Old Dam
Top of Old Dam
Old Spillway lined with Timber
Ground Surface
Center Line of New Dam, Contour 125, on North Face of Old Dam
Culvert
Dobbins Creek on
Center Line of New Dam
Cast Iron Pipe
Vertical Scale of Feet
PLAN OF DAM AND SPILLWAY
Scale of Feet
0 50 100 150 200 250
Toe of New Dam
North To
Top of New Dam
Top of Old Dam
Toe of both Old and Ne
Timber Cribs
Masonry Arch
Rock Drain
End of Wood Pipe
Rock Wall
Site of 6" Pumping Plant in 1901
Small Stream fed by Springs
Discharge Pipe from Pumps Riveted Steel 30" Diam.
Trestle
Motor House
Trestle
Rock Crib Dam
Old Pipe, built in 1860, taken up in 1902
Channel of Dobbins Creek
DOBB
BUIL




# PLAN AND SECTIONS,
## OF THE
# DOBBINS CREEK HYDRAULIC-FILL DAM,
## YUBA CO., CAL.
## BUILT FOR THE BAY COUNTIES POWER CO.

*Third.*—It must have slopes sufficiently flat to be stable under all conditions of saturation from the water in the reservoir, or from soaking rains.

*Fourth.*—The elevation of its crest above the highest water line must be sufficient to insure against the possibility of the dam ever being overtopped by extraordinary freshets, due to cloud-bursts, or to waves driven up its inner slope by gales of wind, or to a combination of these contingencies.

*Fifth.*—It must not settle, crack, or show any sign of change or movement after final completion, and when put into service.

These requirements may be fulfilled in building earth dams by the usual methods of moistening, rolling and tamping, by proper precaution in the selection of materials, and by the exercise of great vigilance and care in construction; and, where the dams are of moderate height, not exceeding 30 or 40 ft., they are generally successful, with rational precautions in the important matter of size of spillway, even if the materials are not placed with such extreme care. Where the height exceeds 100 ft., however, these methods, in all ordinary situations, lead to excessive cost, and a form of construction is requisite which will permit of the proper gradation of materials and their perfect consolidation in a manner which will insure water-tightness, avoid future settlement and, at the same time, accomplish the handling of large masses of material rapidly and at moderate expense.

It is believed that this cheaper and more efficient method has been found and demonstrated in a definite and positive degree by the perfected system of construction known as the "hydraulic-fill," which had its origin in the hydraulic mining regions of California. In this system the entire work is done by the agency of water, which is brought in large volume to the dam site in ditches and pipes, and delivered through the nozzle of a flexible and easily controlled device called a "hydraulic giant," or "monitor," with which hydraulic mining is performed. The stream, issuing from the nozzle of the monitor with a velocity of from 100 to 200 ft. per sec., is directed against the face of a hill containing the materials desired for use, and, by undermining, cuts and loosens everything in its path except the solid rock, and even this, if seamy or stratified, cannot resist its force. The mass, thus disintegrated, is rapidly

washed with the water down the steep sluiceway provided, and is conveyed through flumes and pipes to the several points on the dam selected for the deposit of the different grades of material, their final position depending upon their respective degrees of fineness.

Having had occasion to use this system in several important dams, the writer has been urged to give the profession the benefit of his experience in this somewhat novel type of construction. This he cheerfully does in the following paper, prepared in the few and widely separated leisure moments of a busy life, mostly on railroad trains, or trolley cars.

## The Lake Frances Dam.

As an example of unusual difficulties and adverse conditions successfully overcome where other methods have failed, the repair and enlargement of the Lake Frances Dam by the hydraulic method is, perhaps, the most conspicuous which could be selected.

This dam is on Dobbins Creek, Yuba County, California, about 35 miles from Marysville and 2 miles from the Colgate power-house of the Bay Counties Power Company (subsequently merged with the California Gas and Electric Corporation), and was built originally by that company, in 1899, to form a small reservoir for emergency service. It is on a little tributary stream, the water-shed of which is only 6.5 sq. miles above the dam, from which the run-off yields a discharge fluctuating from practically nothing to an extreme flood flow of about 1 000 cu. ft. per sec. The dam is about 400 ft. in elevation above the penstock of the power-house, which receives its water supply from the North Fork of the Yuba River, through a wooden flume, 9 miles long, built in the rocky cañon of that stream. The flume is subject to occasional interruption from falling rocks, and, in such an emergency, the small reserve storage of the Lake Frances Reservoir is drawn upon for a few hours at a time in order to maintain the load. The original dam of 1899 was built with a maximum height of 50 ft., a top length of 992 ft. and side slopes of 2 on 1, outside, and 3 on 1 on the reservoir side. The crest width was 16 ft., at a height of 4 ft. above the spillway level. The latter was excavated to a width of 40 ft., in earth, and was lined with a wooden flume of 2-in. plank.



FIG. 1.—BREAK IN ORIGINAL LAKE FRANCES DAM. LOOKING UP STREAM.



FIG. 2.—NEAR VIEW OF RIGHT SIDE OF BREAK IN EMBANKMENT OF LAKE FRANCES DAM, SHOWING ROOTS EXPOSED BY THE BREAK.

The reservoir formed by this dam covered an area of 42.67 acres, and had a capacity of 30 545 000 cu. ft.

The site for the dam, as well as a large part of the reservoir basin, was heavily timbered with pine forest when construction began, and had to be cleared and grubbed to get at the material in the borrow-pits.

The embankment, for two-thirds of its length from the south end, was built with slip and wheel scrapers, the earth being spread in 6 and 8-in. layers, and moistened and rolled in the customary manner. The remainder was built late in the season, when the water supply had practically failed. No attempt was then made to place the material in layers; in fact, toward the end there was such haste to finish that the earth was dumped in the most convenient way, as in an ordinary railway embankment. Much of the surface of the steep hill slope on the north end was not even cleared of stumps and roots, as discovered subsequently. As the dam had been designed by a reputable firm of engineers, of San Francisco, and built under their supervision, it was considered to be as secure and perfect in construction as any dam of that character could be, when made by such methods and with the kind of earth available. This earth consisted of red clay and gray sandy soil, resulting from the disintegration of syenite devoid of mica. In the valley proper it contained a slight admixture of gravel and enough vegetable mould to constitute a dark loam. On the hill slopes, where the mass had not been disturbed since the processes of Nature had converted it from soft rock to clay and sand, the material was composed chiefly of red clay, containing angular fragments of rock, with occasional streaks of gray sand. The clay was unstable when saturated, but very firm when the surplus water had been drained from it. The sand would stand vertically in excavations.

*Rupture of the Dam.*—A few days after the dam had been completed, and following a rainfall of 9 in. in 36 hours, the reservoir filled very rapidly, and when the water had risen to within 6 ft. of the spillway, or 10 ft. below the crest, at 11 A. M., on October 21st, 1899, it was suddenly ruptured by a great crack at the north end, due to settlement, which allowed the water to escape with rapidly accelerating force, creating a gap, 98 ft. in width, measured along the crest of the dam, and from 30 to 40 ft. wide at the bottom.

The first alarming symptom noted by the engineer in charge was a considerable leakage along the outlet pipes at the toe of the dam. A few minutes later, a large stream appeared near the steep bank, more than 100 ft. west of the original creek channel, and about 20 ft. above the base of the dam. This enlarged with great rapidity, extending to the top, and, accompanied by a great roar of rushing water, scoured a new channel deeper than the old bed of the stream. The reservoir was emptied within 1 hour to within 23 ft. of the 16-in. scour pipe at the bottom.

Strangely enough, a triangular section of the embankment resisted the erosion of the escaping waters, and held back a pond covering more than 10 acres and containing 2 500 000 cu. ft. This natural weir in clay soil had a sharp crest at the upper slope line, over which the water dropped almost vertically into a hole 28 ft. lower, which had been excavated by the flood some 7 ft. deeper than the original creek channel. By building a temporary flume, 12 ft. wide and 4 ft. deep, at an angle of 45°, from the lip of this earthen weir into the hole below, the weir was preserved, and subsequent floods of the seasons of 1899-1900 and 1900-01 were carried past the dam in that way, with the aid of a plank fence on top of the weir.

The volume of the original dam was 80 265 cu. yd., of which 16 160 cu. yd., or 20%, were washed away by the break and had to be replaced.

*Repair and Enlargement of the Dam.*—During the summer of 1900 the writer was engaged to report on the repair of the broken dam, and, after an examination of the site and the materials available, he recommended that the hydraulic sluicing process be used to loosen, convey and solidify the earth, provided that further experiments should demonstrate the soil to be suitable. This latter qualification was due to the fact that, in its dry state, the clay, when placed in water, exhibited no plasticity, but dissolved and floated off in a muddy cloud, although when moist it was solid and firm. It should be explained that in the long, dry summer, without rain for months, the clay soils of California lose their moisture entirely, and crack to great depths, unless protected from the sun. When tested in this condition, by immersion, the clay seemed to be devoid of all cohesion, and was apparently about as promising a material for dam building as so much pea soup. When settled and drained,



FIG. 1.—LAKE FRANCES DAM. APPEARANCE OF THE OLD DAM AND EMPTY RESERVOIR, AUGUST 31ST, 1901.



FIG. 2.—MASONRY OUTLET CULVERT BUILT IN LAKE FRANCES DAM.

however, the clay, thus treated, resumes its tough, plastic and impervious characteristics.

The date of this report was so late in the season that it was evidently inadvisable to assemble a plant and begin the repairs that fall, the rainy season being too near at hand. In the following spring, the subject was again taken up, and the writer was asked to take charge of the construction. He associated with himself J. M. Howells, M. Am. Soc. C. E., who made an independent investigation and report in the latter part of March, 1901, corroborating the writer's recommendation to use the hydraulic method of handling the work. This report was accompanied by such a conclusive series of tests of material taken from test-pits as to set at rest any fear of unfavorable results from the use of water in doing the work. In this examination Mr. Howells was assisted by F. S. Hyde, Hydraulic Engineer, who had been Engineer-in-Charge of the construction of La Mesa Dam, California, and who, as Resident Engineer, subsequently conducted the work on the Lake Frances Dam to completion. Mr. Hyde is now carrying on similar construction for the Mexican Light and Power Company, Limited, at Necaxa, Mexico, where the two highest earth dams in the world are being built by this process under the supervision of the writer.

Mr. Howells, who had had previous experience in the building of two important dams by this process, at Tyler, Tex., and La Mesa, Cal., regarded it as unwise to repair the dam by simply filling the gap, as it would subject the remainder of the embankment, which had already failed at one point, to the possibility of a repetition of the same disaster, as well as subject the old and proposed new parts of the dam to unequal settlement. Therefore, he recommended that a heavy layer of earth be placed against the upper slope, of sufficient thickness to give an impervious core of selected fine clay between porous zones of coarse, stable material—one of which, next to the dam, should be of sufficient thickness to drain properly the clay core down along the slope of the old embankment to a stone drain, planned to be carried along its upper toe, and connected with a drainage pipe which had been provided originally for carrying off some little springs in the base. The outer permeable layer of stone and sand was required to give stability to the 3 on 1 slope of the outer face. These three layers, in his judgment, required

an aggregate thickness of 125 ft., measured horizontally. This plan, if carried out simply as a repair of the old embankment, would have left the dam with a crest width of 141 ft. With this broad base it was evidently safe to add 27 ft. to the height of the dam. To make such an addition involved the handling of only an additional 81 371 cu. yd. with the same plant that would have to be installed for placing the 133 782 cu. yd. in the break and north face. It was shown that, by this addition to the height, the storage would be increased from 30 540 000 to 101 951 000 cu. ft., extending the area of the lake to 92.33 acres. The extension of the height proposed increased the top length of the dam to 1 300 ft.

The super-elevation of the crest over the spillway was to be 6 instead of 4 ft., as originally built, and it was recommended that the new spillway be increased to a width of 80 ft. in addition to a 5-ft. culvert through the dam near the bottom, to be opened on a rising flood before the reservoir was entirely full. The spillway will be described later in more detail. These recommendations were concurred in by the writer, and the plans being accepted by the company, the work was ordered to be commenced at once.

*Hydraulic Sluicing with a Pump.*—One of the obstacles encountered in carrying out the hydraulic method of construction was the lack of a gravity water supply at sufficient elevation to do the work of sluicing. For the most rapid and efficient service, water should be used under a pressure of from 100 to 150 lb. per sq. in. at the nozzle of the monitor, and in a volume of from 10 to 15 cu. ft. per sec. In this case the only water available was Dobbins Creek, the flow of which is reduced for months during the dry season to about 1 cu. ft. per sec., and at times runs as low as 0.06 cu. ft. per sec.—a mere trickle. To meet this emergency, a small crib dam was built some 300 ft. below the main dam, by which 150 000 gal. were accumulated before sluicing began, and a two-stage tandem centrifugal pump, which had been nearly completed on a previous order from the company for use near Colgate, was ordered finished for this service. This pump had a capacity of 6 cu. ft. per sec., under a pressure of 120 lb. per sq. in. at the pump, delivering through a line of 20-in. pipe, varying from 300 to 700 ft. in length.

As a considerable length of time would be required to secure the delivery of the pump and motor, it was determined to commence



FIG. 1.—LAKE FRANCES DAM. SLUICING PLANT USED WITH SIX-INCH CENTRIFUGAL PUMP FOR FILLING THE BREAK.



FIG. 2.—LAKE FRANCES DAM. LOOKING UP INTO THE RESERVOIR FROM THE TOP OF THE ORIGINAL DAM. AUGUST 31ST, 1901.

sluicing into the break with a smaller pump and motor, which could be more readily secured and quickly installed. A 6-in., single-stage centrifugal pump was obtained, was direct-connected to a 30-h.p. motor, and supplied with electric current from the Colgate power-house, 2 miles distant. With this primitive apparatus the work of sluicing began on May 10th, 1901. This pump delivered 1.76 cu. ft. per sec., under a head of 100 ft., and did very good service for more than a month. The muddy water draining from the dam, and overflowing from within the levees thrown up on each slope in the break, after depositing its load of earth, was caught in the little reservoir below, where it was pumped over and over again. At times, the flow of the stream was little more than sufficient to equal the loss by soakage into the earth, and maintain the supply. Several times the water became so muddy as to add measurably to the load upon the motor, and to require momentary stoppage in order to permit the mud to settle somewhat. This shortage of water occurred after the larger pump had been installed. There was an abundance of water during the time the smaller pump was in service—May 11th to June 15th, 1901.

In this way 4 090 cu. yd. of filling in the repair of the break were deposited between May 10th and June 15th, at a cost of 18.27 cents per cu. yd. This was obtained by excavating the hill slope immediately adjoining, and was sluiced into place with 11-in. pipes. This brought the work up to the level of the new masonry culvert, and sluicing was suspended, awaiting the completion of the culvert and the erection of the permanent and larger pumping plant. During this work, done under most disadvantageous conditions, the average ratio of solids deposited to water pumped was about 13 per cent. After August 30th, when the larger pump was installed, the material was delivered through a 22-in. riveted steel pipe, laid on a grade of 3%, and the repair of the break was completed on October 17th. The overflow from this work went to the north face and deposited 5 220 cu. yd.

*New Outlets to the Reservoir.*—The outlets to the original dam consisted of two 36-in. cast-iron pipes, laid in trenches, 15 ft. apart from center to center, about 100 ft. east of the creek bed, and a 16-in. riveted steel "scour pipe," laid at a lower elevation in the creek channel. The two larger pipes were provided with sluice

an aggregate thickness of 125 ft., measured horizontally. This plan, if carried out simply as a repair of the old embankment, would have left the dam with a crest width of 141 ft. With this broad base it was evidently safe to add 27 ft. to the height of the dam. To make such an addition involved the handling of only an additional 81 371 cu. yd. with the same plant that would have to be installed for placing the 133 782 cu. yd. in the break and north face. It was shown that, by this addition to the height, the storage would be increased from 30 540 000 to 101 951 000 cu. ft., extending the area of the lake to 92.33 acres. The extension of the height proposed increased the top length of the dam to 1 300 ft.

The super-elevation of the crest over the spillway was to be 6 instead of 4 ft., as originally built, and it was recommended that the new spillway be increased to a width of 80 ft. in addition to a 5-ft. culvert through the dam near the bottom, to be opened on a rising flood before the reservoir was entirely full. The spillway will be described later in more detail. These recommendations were concurred in by the writer, and the plans being accepted by the company, the work was ordered to be commenced at once.

*Hydraulic Sluicing with a Pump.*—One of the obstacles encountered in carrying out the hydraulic method of construction was the lack of a gravity water supply at sufficient elevation to do the work of sluicing. For the most rapid and efficient service, water should be used under a pressure of from 100 to 150 lb. per sq. in. at the nozzle of the monitor, and in a volume of from 10 to 15 cu. ft. per sec. In this case the only water available was Dobbins Creek, the flow of which is reduced for months during the dry season to about 1 cu. ft. per sec., and at times runs as low as 0.06 cu. ft. per sec.—a mere trickle. To meet this emergency, a small crib dam was built some 300 ft. below the main dam, by which 150 000 gal. were accumulated before sluicing began, and a two-stage tandem centrifugal pump, which had been nearly completed on a previous order from the company for use near Colgate, was ordered finished for this service. This pump had a capacity of 6 cu. ft. per sec., under a pressure of 120 lb. per sq. in. at the pump, delivering through a line of 20-in. pipe, varying from 300 to 700 ft. in length.

As a considerable length of time would be required to secure the delivery of the pump and motor, it was determined to commence



FIG. 1.—LAKE FRANCES DAM. SLUICING PLANT USED WITH SIX-INCH CENTRIFUGAL PUMP FOR FILLING THE BREAK.



FIG. 2.—LAKE FRANCES DAM. LOOKING UP INTO THE RESERVOIR FROM THE TOP OF THE ORIGINAL DAM. AUGUST 31ST, 1901.

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gates, 4 ft. square, placed at the upper toe of the dam, and were to be operated from a light steel tower standing in the water. This tower was erected and the gates in position at the time of the break, but no attempt was made to raise the gates at the beginning of the flood, as the danger was not realized. When the reservoir had partially filled and the pressure increased, it was found that the device for raising the gates was so insufficient that they could not be opened, and the dam would probably have been overtopped had the break not occurred.

The 16-in. scour pipe was provided with a steel tower similar to that controlling the main gates, which was subsequently buried in the embankment, as shown by some of the accompanying photographs.

After the failure of the dam it was found that the cast-iron pipes were badly broken by the pressure of the earth and the softening of the foundation under them. The location of maximum settlement was under the crest of the embankment, and resulted in destroying four joints of pipe in one line and eight or ten in the other. The uninjured pipes, for a length of four joints at each end, were subsequently dug out, and most of them were relaid as a permanent outlet, reaching from the gate chamber to the outer toe of the dam, a distance of 145 ft. The remaining sections, each 180 ft. long, were plugged with clay and left in place.

Beginning at the outer toe of the dam, the new outlet culvert of masonry, before referred to, was built through the embankment at an elevation of 19 ft. above datum (which is 2 ft. above the lowest contour of the reservoir) on a bench cut in the side of the steep bank of the creek in partly decomposed and partly solid rock. It is circular and 6 ft. in diameter as far as the gate chamber, a distance of 135 ft. from the crib or grillage of timber at its upper end. The gate chamber was placed 82 ft. north of the center of the enlarged dam, its position being determined by the location of a hard bit of bed-rock on which it was placed. From the gate chamber outward, a distance of 150 ft., the waste culvert was reduced to a diameter of 5 ft., and consisted of rough rubble, laid in Portland cement, the exterior being made as irregular and rough as possible, so as to form a bond with the puddle of the dam, while the interior was well plastered. (Fig. 2, Plate LXXI, and Fig. 1,



FIG. 1.—LAKE FRANCES DAM. SLUICE PIPE ALONG INNER TOE OF ORIGINAL DAM, FOR DEPOSITING COARSE, POROUS MATERIAL.



FIG. 2.—LAKE FRANCES DAM. SLUICE PIPE USED WITH SIX-INCH PUMP, SHOWING GRIZZLY AT END.

NOTICE

Plate LXXII). The 36-in. outlet pipe laid adjoining the culvert, between it and the high bank, was surrounded with masonry, like an arch, and was separated from the pipe by a small space of 1 in. at the bells.

The 4-ft. gates, removed from their original position, were placed side by side in the gate chamber, one of them connecting with the 5-ft. waste culvert, which discharges freely at the outer toe of the dam, and the other with the 36-in. cast-iron pipe, which, in turn, was subsequently coupled up with a line of wood-stave pipe, 24 in. in diameter and 2 miles long, which conveys the water to a chute leading down to the penstock of the power plant.

The gates were covered with a hemispherical dome of masonry, through which the gate stems were carried to the top of the dam in 6-in. pipes supported by a trestle tower. The culvert, pipe arch and gate-chamber required 522 cu. yd. of masonry, in which 480 bbl. of cement were used. The entire cost of this outlet was $8 540.50, including the reclamation of pipe, gates and towers, the building of the inlet grating, 16 by 16 by 12 ft., the resetting of gates, and the relaying of pipe, but not including the cost of the cement, which increased the total to about $11 000.

There were special reasons justifying this expense, one of which was the desire on the part of the management to be able to waste water in considerable volume at any stage of water in the reservoir, so as to anticipate a great flood, such as produced the previous disaster. Another reason was the treacherous character of the material through which the spillway had to be constructed. It was manifest that had the water ever reached the original spillway, and gone over it for a few hours, it is probable that it would have washed out a hole similar to the one made in the dam, as the flimsy wooden lining would have been easily undermined by leakage through, under and around it, and thus have been rapidly destroyed. Fortunately, it was never put to the test, and the lumber reclaimed from it proved to be useful in subsequent work.

*The Main Sluicing Operation.*—The outlet culvert having been partially completed, and the pump and motor finally delivered and erected (after long delay due to a general strike of machinists in San Francisco), sluicing operations were resumed on a larger scale on August 30th, 1901, by which date it had been hoped to

have nearly completed the dam. The work had been in progress for 5 months and it had been expected that it would be finished before October, consequently the delays were exasperating and costly. The pumps were belt-connected with a 350-h.p. synchronous motor, which required an exciter and a smaller motor to start it. Electric current was supplied at 2 400 volts, by a 2.5-mile transmission line, built direct from the Colgate power-house. The pump suction was connected with the adjoining sump in dry weather, but later, when water had accumulated in the restored reservoir, increased head was given by connecting with the wooden discharge pipe leading to Colgate. When the new pumps were erected, with sufficient power to give the head needed for more efficient execution, the monitors were moved up to a new position at a higher level than could be reached by the small pump, and the excavation was directed so that the new spillway channel would be opened out for future use. To this end, one line of pipe, with a monitor attached, was laid so as to make a face in the south end of the spillway next the pump-house, and another, branching from the main, attacked the north end. These were not put into action simultaneously, but, by having two lines of pipe to be used alternately, the necessary change of position could be made without other interruption than that of moving from one line to the other the one monitor provided.

The first work of the new plant was to complete the filling of the gap in the original dam, and 9 620 cu. yd. were then deposited from August 30th to October 17th. This work was much hampered by the contracted area to which it was reduced, requiring periodical suspension of work in order to allow for proper settlement and drainage. Levees, 1 or 2 ft. in height, were maintained along the up-stream and down-stream slopes, and were composed of the most stable material brought down by the water, while the fine clay mud was deposited in the pond of water confined between these levees. The excess of water was drained from this pond by flumes at one end of the work, or by a pipe siphon, or both, and returned to a pond at the north side of the dam, in the zone called the "North Face." By this means 5 220 cu. yd. of material were collected from the overflow.

Sometimes, however, the mass became so soft as to cause slips and sloughing down the slopes, due to the lack of sufficient coarse



FIG. 1.—LAKE FRANCES DAM. LOWER FACE OF DAM AT BREAK, RIP-RAPPED WITH ROCK.



FIG. 2.—LAKE FRANCES DAM. SLUICING ON THE BREAK APPROACHING THE TOP.

gravel, rock and sand to afford the desired friction and requisite drainage. This generally occurred during the temporary absence of the engineer, and was caused by the use of material on the face of the dam which was not sufficiently porous. During all this filling of the break, as well as during all subsequent work, the water contained in the fine mud which composed the bulk of the interior of the dam, was constantly being pressed out, as the settlement of the mass continued, and appeared as a continuous ooze over the entire face of the slopes.

The theory upon which hydraulic-fill dams are generally planned and attempted to be carried out is about as follows: That the inner third of the dam should be composed of impervious material, or material which, by drainage and natural settlement, should consolidate into a mass which will become impervious to water, and remain in a moist, semi-plastic condition; that the outer half of each of the other thirds should be coarse, porous, open material, through which water, draining from the interior, would pass freely; while the inner halves of the outer zones should be a mixture of the coarse and fine, or a semi-porous material, in condition to act as a filter so as to prevent the escape of any of the fine particles from the inner third, but at the same time allow of the slow percolation of water through it.

In this case, however, the great length of the dam, and the necessity of securing all the material from one side, compelled the use of such low gradients that but little of the rock encountered in the borrow-pits was available. As clay was the preponderating material, there was a constant lack of sufficient rock and gravel to keep the slopes from slipping and sloughing, and finally it was found necessary to resort to the use of brush to maintain slope stability while the embankment was settling and draining.

*Team Work.*—During the filling of the break, a low levee was thrown up, with teams and scrapers, at the toe of the north face, 125 ft. from the toe of the original dam, to form the pond to retain the overflow previously referred to, and the use of teams was continued for the maintenance of the outer slope levee until November 22d, 1901, when brush was adopted for slope building, its use being continued until the dam was finished.

Pine and cedar boughs, and young trees, some 6 ft. long, were

laid with the butts in, and covered with earth shoveled from the pond. There was no trouble with sinking slopes subsequently, and, although it made a somewhat unsightly and rough exterior appearance, the brush performed the service of knitting the mass sufficiently to prevent sliding. Its use was also a measure of economy, as well as necessity, for heavy rains had made the borrow-pits, from which the teams had been getting gravel and sand, quite unapproachable.

During the entire progress of the work, a pond of water and thin mud, from 1 to 5 ft. deep, was maintained on top of the rising dam, and the reservoir was allowed to fill behind it and remain at a height of from 8 to 11 ft. below the top. Thus the stability of the structure was constantly undergoing a crucial test. At one time, when the water had reached a height of 25 ft. above datum, and was suddenly lowered 5 ft., a few cracks appeared on the inner slope, from 40 to 100 ft. long and from 3 to 24 in. wide, caused by the supersaturation of the surface material on the water slope which had not reached its final settlement. These were filled with small stones, and gave no further trouble. It was this manifestation which confirmed the necessity for the use of brush, for which authority had previously been given by the supervising engineers. Had there been from 20 to 30% of gravel, or even less, in the mass deposited on the slopes, this sloughing or slipping on a 3 to 1 slope would not have occurred; or, if it had been possible to keep up dry levees at the edges of the bank with scraper teams, the stability of the slopes would have been secured; but heavy rains and deep mud made it impossible for teams to go out on the embankment for this purpose, and hence brush was the only substitute.

The general plan of building the north slope was to deliver the sluiced materials, as heretofore stated, through a 22-in. pipe, placed on a high trestle, running parallel with the axis of the dam, and far enough inside the slope lines to reach the slope with lateral flumes of moderate length. The posts of these trestles were necessarily left buried in the embankment which rose around them. The trestles were of varying length, according to the height of the dam, and had an average height of 25 ft. The first trestle, 215 ft. long, was completed on October 25th. The second was finished on November 16th. The third, 6 ft. higher and 150 ft. longer than the

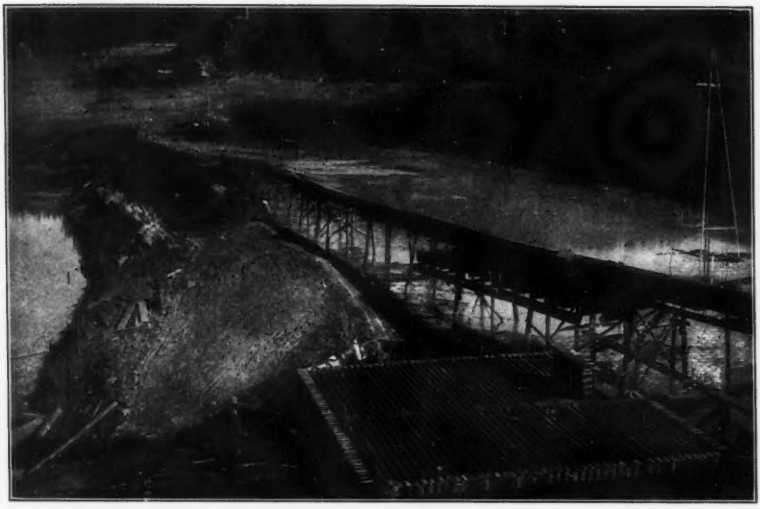


FIG. 1.—TOE LEVEE OF NORTH FACE, LAKE FRANCES DAM, AND INLET CRIB AT HEAD OF SIX-FOOT OUTLET CULVERT.



FIG. 2.—DOME ON GATE CHAMBER, LAKE FRANCES DAM; ALSO TWENTY-TWO-INCH SLUICE PIPE.

second, was completed on November 30th. The fourth, 850 ft. in length, built on a grade of 1.7%, was finished on December 16th, and a week later was raised to give the sluice pipe a grade of 2.2%, on account of clogging. This pipe was 42 ft. in elevation above the base of the dam at its delivery end. To complete the north face, a fifth trestle was erected, with a length of 1 150 ft., on a grade of 2.2%, discharging at an elevation of 59 ft. above datum. This work occupied two weeks, and was finished on January 21st, 1902. The final trestle, with which the additional height of 27 ft. was built, was begun on April 17th and completed on May 2d. Its entire length was 1 560 ft., besides thirteen branch trestles and flumes, reaching to the slopes on either side, as shown in Fig. 1, Plate LXXX. The highest bent in this trestle was 40 ft. above the dam, and there were 100 bents in the main and 33 in the lateral trestles.

The pipes laid on the trestle were joined by key bands of sheet iron about 4 in. wide, made so as to be quickly unjointed by driving out a key and slipping off the band. Thus delivery of a part or the whole discharge of the pipe could be made at any point desired. Bent or curved plates placed under the joint served to deflect the stream of earth-laden water to the steep lateral flumes reaching to the slope levee.

Work continued throughout a winter of very inclement weather, during which the rainfall amounted to 52 in. Much of the time a night shift worked by electric light, except on very stormy nights. A storm on March 1st was accompanied by high winds, which blew all the pipes off the trestles, one of them being buried and lost in the deep mud. After that the pipes were wired down.

The North Face filling was completed to the level of the top of the original dam on February 24th, 1902, and the entire work of extending the dam to a height of 77 ft. above datum was finished on June 30th, 1902.

The volume in the completed dam, including the original dam, is 280 700 cu. yd., as measured several months after completion, when settlement had ceased, of which amount, 182 937 cu. yd. were deposited in the period of 253 days, between October 19th, 1901, and June 28th, 1902.

The aggregate of the weekly measurements taken during this

period was 195 293 cu. yd. of material deposited, or 12 356 cu. yd. in excess of subsequent measurement in the bank.

A record of the actual time of sluicing shows an aggregate during this period of 1 581 hours, or a little more than 25% of the total time. Omitting Sundays and half the nights, the sluicing, in shifts of 10 hours per day, was carried on in about one-half the maximum available time. The other half was lost by reason of stoppages required for building trestles, and also from lack or shortage of power, as various accidents at the power-house compelled a suspension of pumping for periods of several hours and even days.

The volume of water used was carefully measured, and found to vary from about 4.5 to 7.0 cu. ft. per sec. The total quantity pumped in the period stated was estimated at 30 740 000 cu. ft., while the volume carried by the water and deposited in the dam amounted to about 4 940 000 cu. ft. of solids, or 16.6% of the water. This was in addition to about 2 or 3%, carried in suspension, which finally drained off in the tail-race and back into the reservoir.

The weekly percentages of solids carried by the water varied greatly with the conditions encountered. When the power was not restricted, and the water pumped was not overloaded with mud, when the bank against which the monitor was cutting exceeded 25 to 30 ft. in height so that the jet would do rapid execution, and when stones and roots were not too abundant in the pit, and the delivery pipe did not clog on account of too light a grade, the material poured in rapidly, and the ratio was maintained at from 20 to 30%, and ran from 32 to 38% for several weeks. The highest of all showed 47.7 per cent. The minimum week's run gave 6.1% average solids. The best week's work was 22 350 cu. yd., deposited in 94.5 hours, or 236 cu. yd. per hour. During that week 6.5 cu. ft. of water per sec. were used, and the ratio of solids to water was 27.2 per cent. The average work performed was 127.3 h. p., while the recorded electric energy consumed was 176 kw., or 236 h. p., showing a combined efficiency in pump and motor of 53.9% (motor 90%, pumps, 59.9%).

The maximum quantity of material moved as a weekly average was 443 cu. yd. per hour; the minimum, 47 cu. yd. per hour, and the mean, 123 cu. yd. per hour.



FIG. 1.—LAKE FRANCES DAM, SHOWING DELIVERY OF WATER AND EARTH FROM PIPE ON NORTH FACE.



FIG. 2.—LAKE FRANCES DAM, NOVEMBER 6TH, 1901. FROM SOUTH BORROW-PIT, LOOKING ALONG AXIS OF ORIGINAL DAM.

The maximum pressure shown by the water gauge at the pump was 118 lb. per sq. in.; the minimum, 98 lb.

The maximum pressure recorded at the nozzle of the monitor was 75 lb. per sq. in.; the minimum, 38 lb.

The maximum power, measured by electric ammeter at the pump, was 324 h. p., and the mean, 236 h. p.

The total power used during the period covering these statistics, embracing almost the entire work, was estimated at 410 800 h.p-hr. At a cost of ½ cent per h.p-hr., this would amount to a total of $2 054, or about 1 cent per cu. yd. of material moved.

The minimum cost for labor on any one week's work averaged 3.8 cents per cu. yd., sluiced and deposited in the dam. The average labor cost was about 15 cents per cu. yd., and the total cost was probably less than 20 cents per cu. yd., including all power, materials and plant. Under more favorable conditions, such as could be secured in many other localities, the work could have been performed for a fraction of this cost. These improved conditions, easily attainable in many localities, may be briefly noted as follows:

(1).—Constant, uninterrupted, electric current, in sufficient volume to do the work required, if the water be supplied by pumping, but preferably a gravity supply of 10 to 15 cu. ft. per sec., or more than double that which was available in this case, giving greater carrying power and doing more than double the work with the same force of attendants;

(2).—Shorter top length of dam, permitting the use of steeper gradients in the sluice-boxes and delivery pipes, and consequently giving higher velocities, and ability to move much of the rock which in this case had to be left in the pit;

(3).—A larger proportion of sand, gravel or broken spawls of stone less than 10 or 12 in. in greatest dimensions, which would have rendered the slopes stable without the use of brush, and would have avoided the expense incident to the cutting and placing of brush, or the building of levees with teams.

The fact that a considerable portion of the filling was made at a cost of less than 5 cents per cu. yd. is an indication of what

ought to be achieved on a larger scale, with all materials favorable, a gravity water supply of adequate volume and uninterrupted delivery, and a plant planned for and perfectly adapted to the work.

In the excavation of 10 540 cu. yd. from the spillway, the actual cost was only 1.4 cents per cu. yd., while the channel below the spillway, excavated with the hydraulic monitor to the extent of 9 150 cu. yd., cost 3⅛ cents per cu. yd. Under ideal conditions, this low cost might be maintained as the average of an entire embankment.

*Settlement.*—The Lake Frances Dam was constantly undergoing settlement as the water was being squeezed out of it. This was observed by the distortion of the flumes and pipe trestles, and the slope boards on the slopes. The greatest amount of settlement, measured on the posts of trestle No. 5, was 3.43 ft. From July 8th to July 28th—20 days—the maximum settlement observed was 0.4 ft. The original dam, after being re-saturated with water from the wet embankment built against and over it, settled very greatly, and reached a maximum subsidence of 2.5 ft., although it had been exposed to the rains of two previous winters, and was supposed to have reached its limit of settlement before the reconstruction work was commenced.

A measure of the compactness of the earth put in by this method, compared with the same material in its original condition in the bank, was afforded by exact measurements of the main borrow-pit and the embankment made from it. Contours of the original surface were carefully taken before excavation and again afterward, and the areas and volume ascertained by planimeter. The results showed that the material in the dam was only 82.6% of the volume taken out of the borrow-pit. A portion of this difference of 15.4% was material carried away in suspension and deposited in the reservoir. Some tests of this overflow waste indicated that it might have averaged 4.4 per cent. The remaining 11% of shrinkage by the solidifying action of water is suggestive of the practical efficiency of this method of handling earth, although there is some uncertainty as to the estimate of average volume of overflow. Under unfavorable conditions it may reach as much as 35% of the total solids carried, as shown by the fact that, while 9 620 cu. yd. were being deposited in the repair of the break above the level of the



FIG. 1.—LAKE FRANCES DAM, JANUARY 29TH, 1902. TRESTLE NO. 5, 1 150 FT. LONG; DISCHARGE END AT ELEVATION 59 FT. ABOVE DATUM.

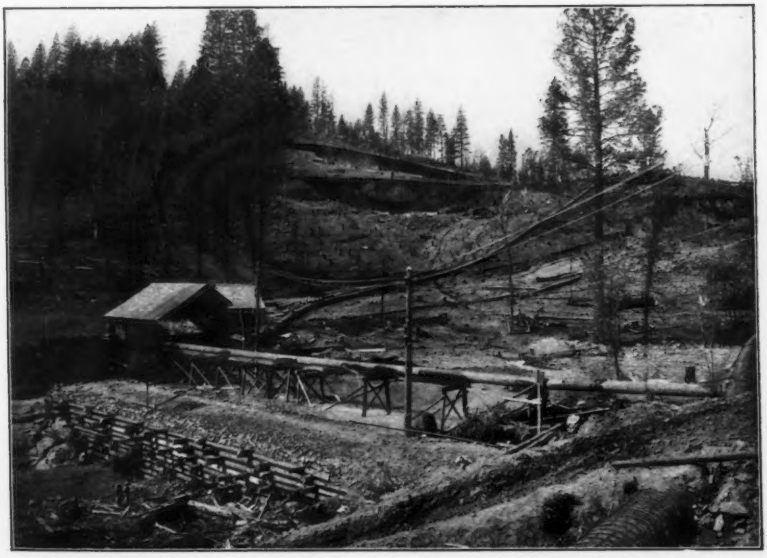


FIG. 2.—LAKE FRANCES DAM CONSTRUCTION. PUMPING STATION, SHOWING SUCTION PIPE CONNECTED TO TANDEM CENTRIFUGAL PUMP. CRIB DAM IN FOREGROUND BUILT TO STORE WATER FOR EARLIER OPERATIONS.

culvert, 5 220 cu. yd. were deposited from the overflow on the North Face. From the general appearance and condition of hydraulic-fills generally, it seems doubtful if it be practicable to secure such density and compactness of earth by any other process, at many times the cost.

To build the dam, a borrow-pit, covering 7.12 acres, was excavated to a mean depth of 21.5 ft.

*Precautions Required.*—The plan of dumping all the sluiced material at the edges of the slopes resulted in building them up rapidly, while the gradients toward the center were flattened as more and more of the coarser particles were dropped, and, with a greatly lessened grade, the water, after depositing all but the finest mud, moved slowly toward the farther end, where it was returned to the reservoir. The 2 or 3% of the mud which it still carried into the pond was rather beneficial than otherwise. At times there was a tendency toward the formation of strata of almost clear sand extending from the sides to or beyond the center. This was the result of carrying the levees too high, or depositing for too long a time in any one place, thus increasing the gradients toward the center core. Where such local strata were discovered, the remedy was to distribute the deposit of tailings more evenly, and also to break up the strata by thrusting planks down into the soft mud, as deeply as they could be driven by a man's weight, and then withdrawing them. This work was followed in several regular, continuous lines, parallel with the longitudinal axis, from a raft or barge, floating in the pond. It appeared to be effective and satisfactory, permitting silt to enter where the plank had been withdrawn, and thus establishing breaks in the continuity of the sand strata. This tendency is one of the numerous details of construction requiring the exercise of due precaution, watchfulness and skill. It is not an automatic process by any means. The formation of sand streaks is more particularly noticeable as the embankment becomes narrower near the top. In the writer's opinion, it is a matter of sufficient importance to justify a material increase in the thickness, and superelevation, of the dam above the spillway level.

*Novel Construction Features of the Spillway.*—The lack of anything like bed-rock, of a solid and reliable character, in the hills on

either side of the dam, which would serve as a foundation for the spillway, necessitated a resort to a novel plan for its construction. About 500 ft. below the dam, on the west side of the creek, an outcrop of hard porphyritic bed-rock appeared for a short distance, protruding through the surrounding soil like an isolated chimney of ore. The top of this rock was about 15 ft. below the level fixed for the crest of the spillway, and a channel was excavated from the spillway to the rock on a grade of 1 per cent. A water-cushion basin was arranged, into which the water overflowing the spillway could drop, the bottom of which was level with the top of the rock 500 ft. below. Thus the possible deepening of the canal by erosion between the spillway and the rock was limited.

The spillway was formed by a slab of concrete, 8 in. thick, laid over the surface of the earth, which had been trimmed to an ogee form, the crest being 80 ft. long, with sloping ends; the extreme height of the drop into the water cushion was about 16 ft. The slab was reinforced by sheets of expanded metal overlapping one another at the edges and ends, and placed so as to resist the erosion of the overflow. This metal was held in position by loops of $\frac{1}{8}$-in. wire, 18 in. long, embedded in the concrete every 18 in., the ends being allowed to protrude about 1 ft. When the sheets were laid over the hardened first layer of 6.5 in. of concrete they were effectively wired down to its face by twisting each of these pairs of wires over a sub-division of the metal. Concrete grout was then flushed into all the interstices of the expanded metal, and a plaster coat of cement and sand, in equal parts, 1.5 in. thick, was spread over the surface and given a smooth finish. The plan and sections of the spillway are shown on Plate LXIX, and a general idea of its construction is given by Fig. 2, Plate LXXXI.

*Results Achieved.*—For the first two winters after the completion of the dam it was not permitted to be filled higher than the top of the original structure, because an economical streak in the management inspired an order suspending work before the spillway channel was finally completed to the rock of refuge below, and the superintendent did not like to take chances on its use. Therefore, the 5-ft. waste culvert was kept open a sufficient length of time during these two rainy seasons to prevent the reservoir from filling higher than the crest of the original dam. In the summer of 1904 the wasteway



FIG. 1.—WEST END OF LAKE FRANCES DAM, SHOWING THE BREAK RESTORED, THE HIGHER DAM NEARLY COMPLETED, THE HYDRAULIC GIANT AT WORK, AND THE MAIN PIPE LINE SUPPLYING WATER TO THE PUMP.



FIG. 2.—HYDRAULIC GIANT IN ACTION UNDERCUTTING THE BANK.

channel was finally completed, and in the winter of 1904-05 the reservoir was permitted to fill. After one of the heavy storms of that season the lake filled to overflowing, with the 5-ft. waste culvert discharging its full capacity; and water ran over the spillway to the depth of 22 in. This severe test established confidence in the dam so fully that the reservoir has been doing maximum service ever since. Opportunity was offered, by an excavation made in 1905 into the body of the dam, to disclose the condition of the material forming the mass. It was reported to be moist, solid, and "cutting like cheese"—evidently very satisfactory. The consulting engineer of the present company has even recommended that the dam be raised again to obtain additional storage. The photographs on Plate LXXVIII show the pits in detail, with the jet from the monitor in operation, although in these pictures the apparatus appears to have been arranged rather more for spectacular effect than for the performance of certain work. In practice, the jet is not thrown so high in the air, but is rather directed to the under-cutting of the face of the bank, from a position as close as safety to pipeman and monitor will admit. It is also played upon the material that has fallen from the face, cutting up the landslides and masses of earth which the under-cut has caused to topple over into the pit with majestic movement and crushing power. When thus jarred and shaken up, most materials yield quickly to the terrific velocity of the torrent directed upon them, and pass off in suspension in the water.

The work must be managed in the pit so that its floor will be constantly "cleaned" up by moving out and washing down all desirable material with the least loss of gradient, water supply and time, keeping the water as nearly as possible fully loaded with sediment, and at the same time excluding perishable trash, and rocks having a flat or angular form which unfits them for carriage through the sluice boxes or pipes without blocking.

### Hydraulic-Fill Dam in Crane Valley, California.

Almost simultaneously with the construction of the Lake Frances Dam, a similar structure was being erected in Madera County, in Central California, by the hydraulic process, but under conditions so distinct as to give the work a peculiar interest. The plans

were prepared by Mr. J. M. Howells, in the capacity of Consulting Engineer, but the work of construction was under the direct supervision of Mr. J. J. Seymour, President of the San Joaquin Electric Company, for whom the work was done. Mr. Seymour has kindly contributed the following account of the construction features:

"The San Joaquin Electric Company had a long-distance electric plant carrying power from a power-house on the North Fork of the San Joaquin River, in Madera County, to Fresno City and neighboring towns in the San Joaquin Valley. The management had found that during three or four months in the late summer and early fall of each year, the natural flow of the stream was insufficient to run the plant to its full capacity.

"The Crane Valley Dam was built to impound some of the excess waters of the abundant winter and spring flow of the streams, to be liberated later in the season as the company's needs demanded.

"The site selected was in the lower end of Crane Valley at a point where the valley contracts into a narrow cañon through which the North Fork River flows. The stream at this point makes a horse-shoe bend around a rocky point, the location of the dam being at the toe of the shoe.

"The general dimensions proposed were as follows:

| | |
|---|---|
| Maximum height | 100 ft. |
| Length on top | 720 " |
| Width on top | 20 " |
| Slope on water side | 2:1 |
| Width of cañon at base | 50 ft. |
| Width 60 ft. higher | 300 " |

"The bottom and sides of the cañon were composed of hard granite formation. Near the stream the rock was extremely hard, but it became less hard as the sides receded from the stream, and near the top on the west side considerable difficulty was experienced in obtaining a sufficiently firm base on which to lay the center core of the dam.

"The hills on either side of the stream have an underlying base of granite which has disintegrated very irregularly, leaving hard exposures at various points, while in places the depth to the solid rock is great. On opening up the borrow-pits the granite itself was found to vary greatly in hardness and cohesion within a few feet, seemingly without change in its chemical formation. The pits would open out in places, showing a vertical face of 30 or 40 ft., the material being unquestionably original granite formation but yielding to water erosion almost like a sand bank. On being under-cut by a jet of water, it would fracture vertically, exactly



FIG. 1.—LAKE FRANCES DAM FROM THE EAST END, SHOWING FINAL TRESTLE AND SLUICE PIPE, AND GENERAL VIEW OF BORROW-PIT.

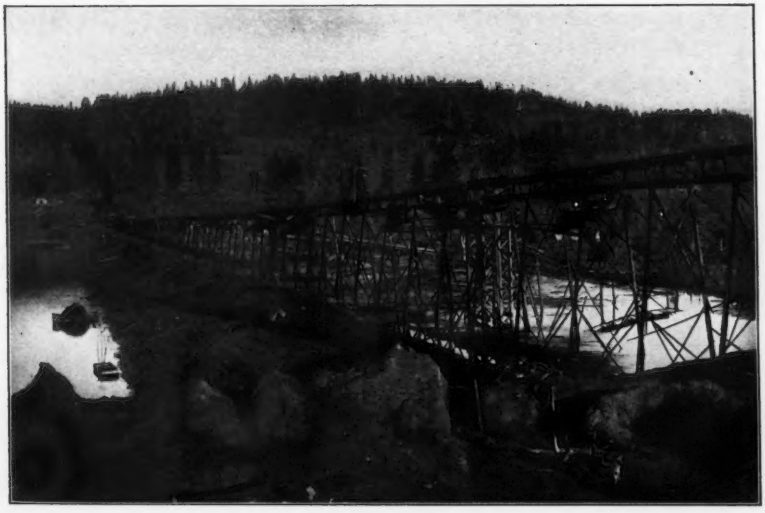


FIG. 2.—LOOKING EAST ALONG LAKE FRANCES DAM, SHOWING OPERATION OF BUILDING UP SLOPES WITH BRUSH.

like a sand bank, and would fall in great masses which would pulverize in falling, and the continued play of the jet of water would immediately sweep it into the flumes.

"A few feet to one side, and its cohesive strength would suddenly increase to such an extent that water would have no effect on it. Or, on being cut with extreme difficulty, immense granite boulders would fall down, and these were so hard that powder would be required to break them up, and sluicing in that direction would be brought to a sudden close. Hence the hydraulicing in this granite formation was restricted to certain zones.

"In other places were borrow-pits which had been filled in by the action of water. The material here showed a large percentage of red clay mixed with sand. When the material from these latter pits was being sluiced on the dam, the workmen had great difficulty in keeping the outer edges of the dam up to the steep slopes at which they were designed, as they showed a tendency all the time to keep sloughing out, due to the lubrication of the contained clay.

"The material from the granite formation, however, seemed to be ideal for hydraulic dam building. Samples of it were taken, thoroughly dried, weighed and washed in a gold-pan, the water being changed until there was no discoloration. The coarse material left behind, consisting of sand with grains of varying size, was dried and weighed again. It was found that the percentage of sand left varied from 70 to 80% of the total material.

"The center line of the dam was excavated to bed-rock, and all loose material, boulders and sand, resting on bed-rock was removed for a distance of about 20 ft. from the center line on the up-stream side. Then a concrete foundation wall, 2 ft. thick, firmly fastened to bed-rock, was laid along the center line. This wall was carried up about 2 ft. in height. In the center of the stream bed it was 5 ft. high. About 9 in. from the up-stream side of this wall a center wooden core-wall of doubled 1-in. sheeting was fastened, by firmly embedding it with concrete of a high grade.

"This sheeting was carried up some 30 ft. above the bottom of the dam. Its object was mainly to prevent the stratification of the material, on being deposited, from extending across the center of the dam. It was also thought that it might act as a safeguard against the percolation of water through the core of the dam after construction.

"It was originally planned to carry this sheeting up to the water line of the reservoir. As the dam building progressed, however, it was found that possible stratification could be effectually prevented by a system of cutting into the plastic material in the central part of the dam, by the pushing down of broad paddles made of 1-in. boards. This process was followed in a systematic-

manner from day to day when sluicing was being carried on, care being taken that the boards or paddles were manipulated so as to make a continuous line of cleavage in the center plastic material from end to end of the dam. These lines of cleavage were repeated at intervals of 2 ft., measured from the center line of the dam, on the up-stream side, and were continued until a distance of 20 ft. from the center line was reached, making a total of eight or ten lines of cleavage each time the process was gone through with. As the workmen were able to shove the paddles into the mushy middle mass some 10 ft., it followed that the cleavage was repeated over and over again. Of course, after each paddle was withdrawn, the oozy material about would immediately fill in behind it.

"The result of this kneading process was so satisfactory that it was not thought necessary, as stated above, to carry the wooden sheeting higher than 30 ft. from the bottom. Toward the sides of the cañon, as the dam building progressed, this height was gradually decreased, until, at an elevation of 60 ft. from the bottom, the sheeting was only extended 6 ft. above the concrete foundation wall. This height was proposed to be maintained to the top of the dam.

"On top of the center concrete wall, against the wooden sheeting on the down-stream side, there was built, in place, a porous cement conduit 3 in. in diameter. This was built along the entire length of the wall. At the lowest point in the stream bed, the two ends were made to empty into a 6-in. porous cement conduit which was laid down the thread of the stream until it extended beyond the toe of the lower slope. The object of this drainage system was to draw off any water that might possibly reach below the center line of the dam, after construction. But, as will be explained later, through a series of adverse happenings, it became a source of menace to the safety of the dam.

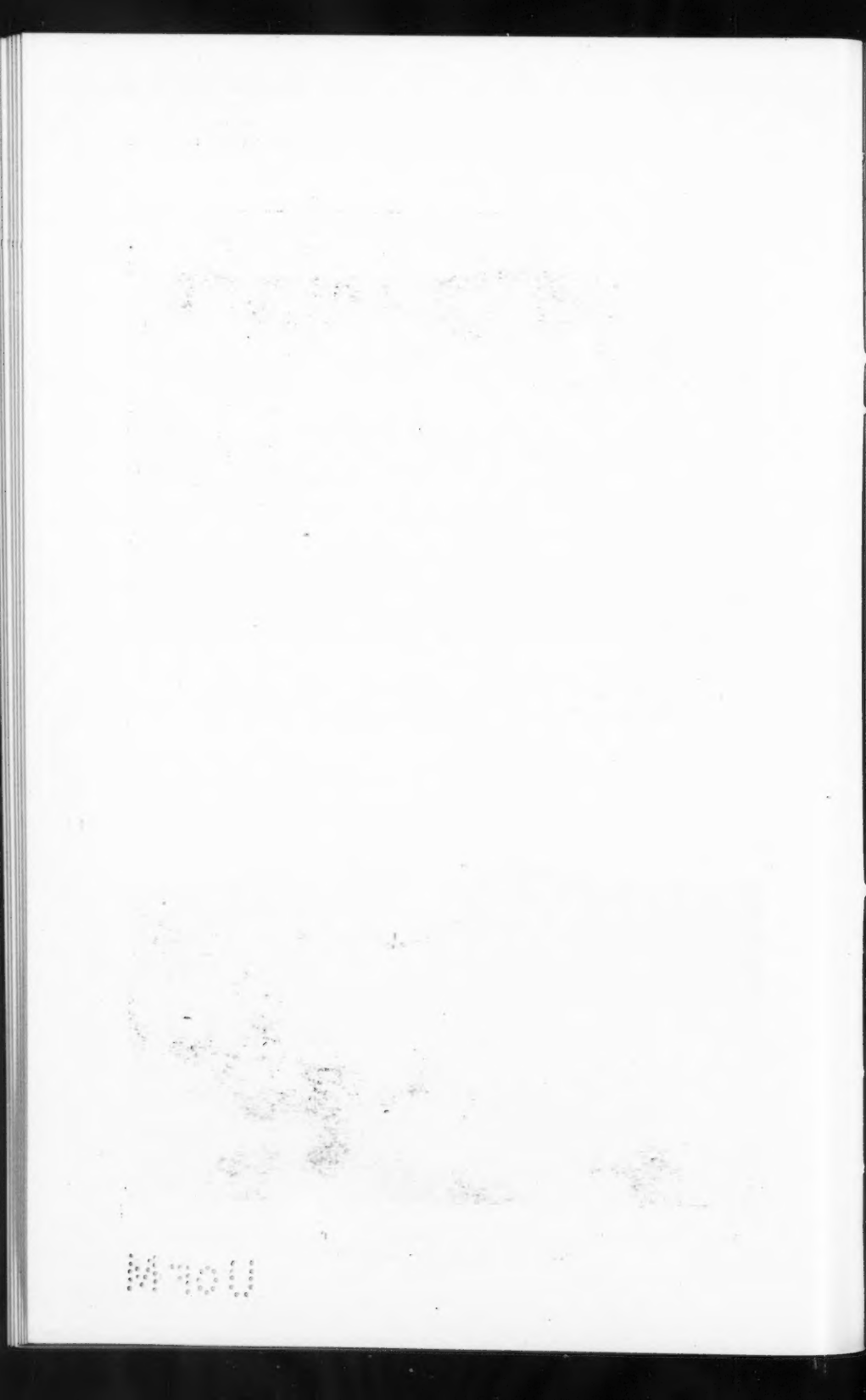
"It had been planned originally to run a tunnel through the rocky point, around which the stream runs at the dam site, to carry the flood waters during construction, and this tunnel was begun. But, after running some distance in, the rock was found to be broken and seamy, with clayey fissures running through it. It showed a tendency to cave in, and was so unstable and uncertain that provision was made for carrying the water of the stream through the dam while in process of construction, by arching over a cut, blasted out of the solid rock by an old mining company for a ditch grade, at a level of 14 ft. above the stream bed. Here the rock was compact and free from fissures. This cut was arched over with masonry for the entire width of the dam. Its size was 6 ft. in width by 7 ft. high. Gates were set in this culvert on the center line of the dam. The culvert was to be bulk-headed just above the



FIG. 1.—HYDRAULIC-FILL DAM BUILDING, SHOWING OUTER LEVEES MAINTAINED WITH BRUSH, DEFLECTING BOARDS FOR DISTRIBUTING SLUICINGS ALONG SLOPE, GENTLE SLOPES TOWARD CENTER OF DAM, AND GRADUAL MOVEMENT OF DRAINAGE TOWARD EXTREME END.



FIG. 2.—LAKE FRANCES DAM COMPLETED, SHOWING THE TOP OF THE BURIED GATE TOWER ON THE SIXTEEN-INCH OUTLET.



gates after the completion of the dam, after which the gates could be closed and water storage begin. Directly above the gates extended a circular shaft, 22 in. in diameter, reaching to the top of the dam. This shaft was made of successive rings of cement pipe 12 in. in height, which were added one at a time as the dam rose. During construction this shaft served to draw off the water used in sluicing, which formed a pool in the center of the dam after it had dropped its load.

"It had been planned to bring the water for sluicing purposes a distance of some 5 miles, by flumes and ditches, from a branch stream having a higher elevation than the top of the dam. Unfortunately, a part of the ditch line was on a Government Forest Reserve, and there was delay in getting a permit to use the ditch over this reserve. It was seen that to wait the slow action of official proceedings would throw the construction of the dam too late in the season to raise it high enough to be beyond possible danger from winter floods, and if construction was postponed another year the company would be again crippled for lack of water. The management, therefore, decided to begin operations by pumping water for sluicing purposes, to be carried on until the ditch right-of-way permit came. This was in the spring of 1901. A hasty change of plans was made, and by the time the snow waters had subsided sufficiently to enable the stream to be forced through the culvert, the company was ready to begin active operations in sluicing material by means of the pump.

"The pump was a Worthington compound duplex, superseded and thrown out of commission by the Fresno Water Company on account of insufficiency of size. It was capable of pumping at the rate of about 60 000 gal. per hr., equal to 2¼ cu. ft. per sec. It was placed on the bank of the stream above the dam site. The water it pumped was carried through an 11-in. riveted steel pipe to the borrow-pits, where it was forced through a "Little Giant" monitor, having a nozzle 2½ in. in diameter. The material to be sluiced was from 75 to 110 ft. above the stream. At this elevation the pump threw a stream with sufficient force to do the work of undercutting required of it effectually.

"Flumes were laid on a grade of 6 per cent. Attempts were made to lessen this grade, but they had to be abandoned because of the clogging of the flumes. Had there been more water, the grade could have been lessened. The flumes were made of 1-in. pine lumber 12 in. wide. This gave them a size of 10 by 12 in., thus being 2 in. more in height than width. They were enclosed on all four sides until the dam was reached, when the top board was left off. Attempts were made to use the V-shaped flume, but the results were not as satisfactory as with the rectangular shape.

"Two sets of flumes were constructed on the dam, one on either side. They were used in alternation. Material was sluiced through the flume on one side until that side was raised to a height from which the heavier particles, making their own grade toward the center of the dam, approached it as near as was thought expedient. Sluicing was then carried on through the other flume, and that side of the dam was raised to correspond with the other. At the bottom of the dam the coarser sand was not allowed nearer the center line than about 40 ft., but as the dam rose and its top width decreased, this distance was decreased correspondingly.

"After both sides were raised, as described above, the water level of the pool, always remaining in the middle of the dam, was raised by adding one of the cement rings to the circular shaft described above, through which the surplus water was allowed to escape. This raised the water level of the central pool about 13 in. The process of sluicing was then repeated. As the dam approached the 60-ft. level, this rise of 13 in. was found to throw the water too near the edge of the dam, and rings 6 in. in depth were added thereafter. The flumes were placed so that when the dam had reached an elevation equal to the lower end of the flume, which, of course, was on the farther side of the dam from which the excavation was taking place, the flume was on the outer edge of the dam. The flume was then raised, moving it toward the center of the dam sufficiently to allow the process to be repeated on the higher level.

"The trestles were made of 2 by 4-in. plank, and generally the 2 by 4-in. pieces could be pried out of the sand and used over again. A hand-spike with a sharp iron spur bolted to its end would generally start the stick from its bedding in sand. The flumes were raised about 10 ft. in elevation each time.

"At short distances along the flume, slotted openings were made in the bottom, through which a driblet of water was allowed to run. This driblet, being from the bottom of the flume, carried with it a large percentage of the coarser particles of sand coming down the flume until they were shoveled out by the workmen to carry up the outer slopes of the dam.

"The great bulk of the water was turned on, as desired, at different points along the flume by sawing the inner side of the flume in such a way that a section of it could be thrown across the flume diagonally, turning all the water out of it at that point. This could then be closed and another opening made as the occasion demanded.

"The sand carried in the flumes, on reaching the dam, was distributed on a light grade until the pool in the central part of the dam was reached. Here almost the entire quantity of sand remaining was deposited at once, forming a bluff bank under the water at

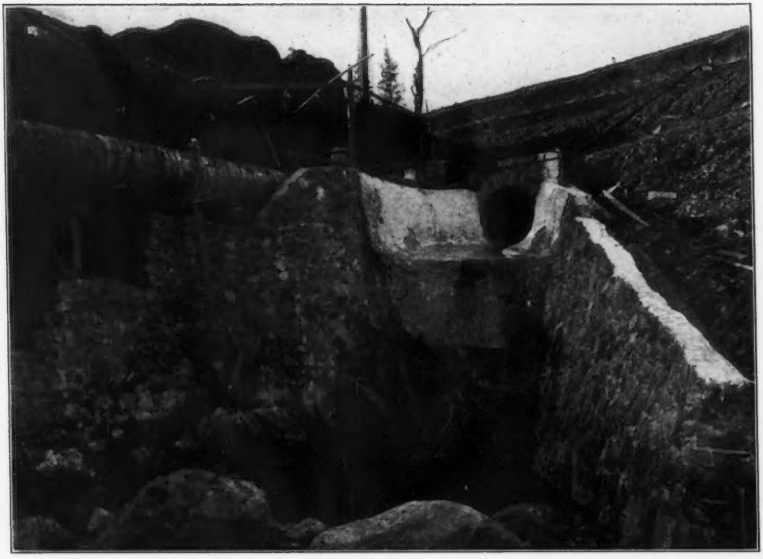


FIG. 1.—LAKE FRANCES DAM. DISCHARGE END OF WASTEWAY OUTLET CULVERT, USED AS AUXILIARY TO MAIN SPILLWAY FOR EMERGENCY RELIEF.



FIG. 2.—SPILLWAY OF LAKE FRANCES DAM, 80 FT. LONG. THE WATER-CUSHION IS FIVE FEET DEEP.

UofM

UBFM

its edge, while the finer particles were distributed throughout the inner section of silt.

"Attempts were made to carry small boulders and rocks through the flume while the process of sluicing was going on, but it was found to be impracticable with the quantity of water and the grades used. It would seem that this method of carrying boulders is only practicable where the rock is mixed with the material to be used, and the grades much steeper or the quantity of water much greater. It was found not to work in the construction of this dam at any stage. We have no data on hand from which to give definite figures as to cost of the movement of material. Like all other dams of this type, when conditions were favorable, and material plentiful, it was moved at an extraordinarily cheap rate. While working in the granite borrow-pits described above, there were days when the material carried in the water exceeded 25% of the quantity pumped.

"About two-thirds of the total quantity of material moved into the dam was carried by the water pumped. The permit to use the ditch came at last, and the final third was ground-sluiced in, the methods of handling the flume being similar to those used in pumping.

"The dam was built to a height of about 70 ft. At this height a secure temporary spillway was afforded, through the horseshoe-shaped hill described above, around which the stream ran. Here it was stopped, as the reservoir capacity at that level was ample for the needs of the company at that time.

"The two faces of the dam were rip-rapped with broken stone gathered from the adjoining hillsides and latterly from the temporary spillway.

"After the sluicing was practically suspended and the force was engaged in finishing the rip-rapping with broken stone blasted out in the process of widening the spillway, there occurred a break in the dam, to which allusion was made in describing the small conduits under the dam.

"Before describing the break, reference will be made to a mishap which occurred some time previously, which was primarily responsible for the damage done.

"In preparing the culvert for turning water through it, the bases of the gates, to be used afterward for letting water out, were firmly embedded in the bottom of the culvert with concrete. This concrete extended several feet up stream from the gate, and was intended to be the base of the bulkhead by which the culvert was to be blocked after the completion of the dam. A wooden door, consisting of a double thickness of 2-in. pine boards, was hinged to the upper side of this bed of concrete, and was accurately fitted to the

culvert, so that when the time came for bulkheading the culvert it could be flapped shut and held in place by the pressure of the water while the concrete bulkhead was being placed. This wooden door was securely fastened down, as was thought, but, through some mishap, when the dam was about 40 ft. high, and during a heavy freshet, the fastening worked loose, the gate flapped shut, and water began to rise rapidly in the reservoir, threatening to go over the top of the dam, the outlet gates not being sufficiently large to carry off the volume of water then coming down stream. In this emergency it was decided that the wooden flap-gate would have to be blown out with powder to prevent an impending catastrophe. After experimenting on two or three bulkhead doors of similar dimensions, which were backed up with sand and blown to pieces on the top of the dam, in order to ascertain the quantity of powder necessary to do this without subjecting the culvert to more shock than was necessary, the door was blown out, the flood passed off through the culvert, and the danger of overtopping the dam was averted. After the water had subsided sufficiently the tunnel was thoroughly examined on the inside and no indications of damage were visible. Unfortunately, as ascertained later, the small, 3-in. cement conduit, extending along the center line of the dam, was shattered, by the upward thrust of the explosion, at the point where it passed over the top of the culvert. The center wall had been omitted here, and the conduit and the cement footing of the wooden sheeting had been fastened directly to the top of the culvert. The cement footing of the sheeting was also badly shattered. Of course, there were no means of knowing this at the time.

"The break began by showing an increase and discoloration in the small quantity of water which had been running through the 6-in. pipe extending below the toe of the lower slope in the middle of the stream. This was watched with dismay, and it slowly increased until it ran about 3 or 4 miners' in. of highly discolored water carrying much sand. It did not increase beyond this quantity, but continued running for several days before its effect was shown on the dam. It was decided that it must be coming from a break somewhere in the 3-in. drain pipe, because of the small quantity of water being discharged, but at that time it occurred to no one to locate the trouble at the point where the 3-in. drain had been shattered, as this was not known. At this time the reservoir was full, almost to the spillway, with the culvert under the dam discharging its full capacity of water.

"The first visible break occurred in the top surface of the dam about 40 ft. from the center on the up-stream side, and a little to one side, vertically, of the culvert under the dam. It began by a



FIG. 1.—CRANE VALLEY HYDRAULIC-FILL DAM, SHOWING METHOD OF LOOSENING THE MATERIALS SLUICED INTO THE DAM.



FIG. 2.—BORROW-PITS FROM WHICH MATERIAL WAS SLUICED TO THE CRANE VALLEY DAM.

subsidence, conical in shape, like a crater, and continued until a depression, some 15 or 20 ft. deep, was made in the dam. Around this crater were several concentric rings of fracture in the top of the dam. The outermost of these were nearly 60 ft. from the center of disturbance. When the subsidence began, great quantities of gravel boulders of varying sizes, and bags of sand, were thrown into the center of it. These disappeared, and when, after several days, the leak stopped, it was supposed that they were the means of checking it. More than 1 000 cu. yd. of material went out of the dam during the leak.

"To remedy the break, a shaft was sunk around the 22-in. circular cement pipe through which the water had been drained while sluicing. The movement of the top of the dam toward the depression had fractured this pipe, and there were other signs which indicated that the seat of trouble might be at its foot.

"On reaching the culvert top with the excavation the break was found. It was also discovered that it had been mended by being plugged with roots and leaves which had been washed into the dam in the process of sluicing.

"The small conduit was plugged with cement, the circular drainage shaft was removed, its opening into the tunnel was closed, and the large exploration shaft was filled up again. The gates were afterward removed to the lower outlet of the culvert under the dam.

"A rational explanation of the causes of the break may be stated as follows:

"*First.*—The small conduit and the footing of the wooden sheeting, where they passed over the culvert, were shattered at the time of the blowing out of the wooden gate, as explained above.

"*Second.*—The continued explosion of blasts, in excavating the spillway about 300 ft. distant, gave a jarring motion to the culvert, and permitted the gradual working of a film of water, probably, along the outside of the large culvert, until it had reached the center of the dam and found its way under the shattered sheeting into the 3-in. drain pipe.

"*Third.*—The center puddled material of the dam was compact enough to admit of a small fissure or water-worn conduit being formed beneath it, but when the point toward the outer edge of the dam to which sand had been allowed to come in sluicing was reached, this had not sufficient cohesion to stand, but poured into and followed the crevice or water-worn conduit to the center of the dam where it reached the 3-in. drain pipe through which it finally discharged.

"At this date (1906), it is announced through the newspapers that the dam is to be raised again to afford more storage capacity.

"It has been in service continually since its completion."

The foregoing graphic account of the construction of the dam and the remarkable break by which it started to flow away after completion is a most interesting illustration of the varying action of the different grades of material which may be used successfully in hydraulic-fill dam building. Evidently, the quicksand which composes the center of the dam is the poorest material of which a dam can be constructed, and yet, when held in place by coarse, stable sand and gravel on the slopes, it is water-tight because of its extremely fine texture, and can be made to constitute one of the important parts of a stable, permanent, safe and useful dam. By no other process, however, could an equally tight and stable dam have been built, except by covering it with an impervious facing, or building a heavy core-wall in its center, either of which would have added to the cost to a prohibitive degree.

HYDRAULIC-FILL AND ROCK-FILL DAMS ON SNAKE RIVER, IDAHO.

The ideal type of earth dam is one where stability of the mass is secured by a heavy embankment of loose rock on the down-stream side, against which the earth fill can be placed by the sluicing method, with an up-stream slope of at least 4 on 1; or, in other words, a combination of rock-fill and hydraulic-fill. The rock-fill affords stability against sliding or overturning, and, at the same time, gives perfect drainage to any seepage which may find its way through the earth. Thus the saturation and sloughing of the outer slopes are prevented, and one source of weakness and cause of failure in earth dams is rendered impossible.

Three dams of this type were built in 1904-05 by the Twin Falls Land and Water Company for the diversion of Snake River into irrigation canals on either side of that stream, in Cassia County, Idaho, under plans designed by W. G. Filer, Manager, P. S. A. Bickel, Chief Engineer, and the writer acting as Consulting Engineer. The construction was under the direct supervision of Mr. M. M. Murtaugh, as Assistant Manager. These dams have some special features which put them in a class by themselves as the first of a type which may be adapted to many other localities to good advantage. At the site selected for headworks, the river was divided into three channels, by two islands of basaltic rock, both of which were utilized for waste ways. The North Channel was the



FIG. 1.—CRANE VALLEY DAM, SHOWING WOODEN FENCE, OR CENTER DIAPHRAGM, WHICH WAS CARRIED UP TO A HEIGHT OF 30 FT. ABOVE BED-ROCK.



FIG. 2.—CRANE VALLEY DAM, SHOWING DISCHARGE OF SLUICED EARTH AT END OF CONVEYING FLUME.

permanent bed of the stream, the other two being dry at ordinary low stages of the river. The Middle Channel carried a considerable volume at medium high water, while the South Channel was never occupied except in extraordinary floods.

To reach the level of the canals and fill them to the depth of 8 ft. above the floor of their headgates, it was necessary to lift the river bodily a height of 49 ft. above normal low water. For this purpose, the dams required to be of the following dimensions:

Main Channel Dam: top length, 340 ft.; height above lower toe, 86 ft.; upper toe, 80 ft.; volume of rock-fill, 39 650 cu. yd.; earth-fill, 58 000 cu. yd.

Middle Dam: top length, 335 ft.; height above upper toe, 56 ft.; lower toe, 81 ft.; volume of rock-fill, 42 800 cu. yd.; earth-fill, 62 850 cu. yd.

South Dam: top length, 560 ft.; height above upper toe, 56 ft.; lower toe, 66 ft.; volume of rock-fill, 34 700 cu. yd.; earth-fill, 48 000 cu. yd.

The total length of the three dams and the intervening spillways and regulating gates, considered as one structure, is about 2 100 ft. Plate LXXXVI.

*Construction.*—The rock-fill portion of the dams was made with slopes of 1½ on 1 on the down-stream side, ¾ on 1 on the up-stream side, and 10 ft. wide at the crest. The base of each dam was stripped of surface soil and loose material, and in the center line of the rock-fill a trench was excavated into the bed-rock, throughout the longitudinal axis and extending up to the top on the sides. In this trench a continuous core-wall or barrier of double 2-in. plank was built from the bottom to within 6 ft. of the top, the plank being laid horizontally, breaking joints, and being spiked to 3 by 6-in. uprights placed 2 ft. apart from center to center. The base of this wooden partition was embedded in concrete, which filled the trench to above the line of the bed-rock, and formed a tight bond with the rock. The trench was from 5 to 6 ft. wide, and the concrete was well rammed on either side as far up as it extended, which was usually from 4 to 6 ft. The loose rock embankment was built on each side of the fence, which was carried up considerably in advance of the rock. For several feet on either side of

the fence the rock was laid by hand with sufficient care to avoid crushing the wood by settlement, and give a continuous bearing of rock against every square foot of the fence. Outside of this the rock was loosely dumped into the embankment from a cableway. The rock was hauled to the site from the south side canal, the excavation of which was in solid basalt for the first 2 miles. In this section the canal was 100 ft. wide on the bottom, and was designed to carry water 8 ft. deep. By the terms of the contract, all the rock in these 2 miles, estimated at 96 000 cu. yd., measured *in situ*, was required to be delivered at the dams if needed. As the total bank measurement of rock in the three dams was only 114 250 cu. yd., and as the 96 000 cu. yd. of solid rock yielded enough loose rock to measure more than 150 000 cu. yd., there was much to spare. This rock generally broke in large masses, was quite hard, and made a very solid embankment.

*The Hydraulic-Fills.*—The function of the wooden core-wall in the rock-fill was to permit the earth embankment built against the rock-fill to be sluiced in place without flowing out through the voids in the rock. The earth available for this work was of one class only, and consisted of the fine, white or grayish soil which covers the entire region to a depth varying from 2 to 20 ft. or more. It is exceedingly fine in texture, an almost impalpable powder, free from grit, and wonderfully uniform. A test made by the writer showed that nearly 90% would pass through a sieve of 10 000 meshes per sq. in. It is classed by geologists as loess or æolian (wind-borne) soil, and probably was deposited originally in the water by the wind. It absorbs water very slowly, like flour, but when once wet packs very solidly and becomes as stable, impervious, and solid as clay, with this advantage that it does not shrink and crack when it dries out. In building the south and middle dams the plan used was to throw up a levee at the upper toe of the embankment with dry earth, hauled in by wheel scrapers or wagons. Between this levee and the rock-fill the bulk of the filling was subsequently sluiced in place by water delivered by centrifugal pump from the river to the earth dump at one end of the dam. The earth was hauled by cars and electric locomotive from borrow-pits a mile or more distant on the south side of the river, and dumped at such an elevation at the nearest end of either dam that the



FIG. 1.—CRANE VALLEY DAM, AT A MORE ADVANCED STAGE. THE SLUICED EARTH AFTER A FEW DAYS' SETTLEMENT, IS ABLE TO BEAR UP A TEAM ON THE OUTER THIRDS, WHILE THE CENTER IS STILL LIQUID.



FIG. 2.—CRANE VALLEY DAM, NEARING THE 70-FT. LEVEL, WHERE SLUICING OPERATIONS CEASED.

water would carry it on a grade to the other end. The grade naturally taken by the earth thus sluiced was from 2 to 4 per cent. The liquid mud freely entered the voids of the rock-fill, and filled them solidly as far as the wooden core-wall. As it rose in height, some slight leakage occurred in the wood partition, but the joints quickly swelled, filled with mud, and became entirely tight. The earth was always 20 ft. or more lower than the top of the rock-fill, and the work progressed at such a moderate rate that the embankments had ample time to settle and solidify. The earth packed so readily that 4 days after sluicing was suspended a team could be driven over the sluiced material without sinking in, although during the time sluicing was in progress a pole could be easily pushed down into the mud 10 ft. or more, particularly at the extreme end, where the water stood longest in the pool. Very little surface drainage was required to get rid of the surplus water. It seemed to sink out of sight and become absorbed in a mysterious way, without showing any sign of reappearance, either at the outer side of the rock-fill or inside the earth-fill. The volume of water used was about 1.5 cu. ft. per sec. It was sprayed upon the dusty earth coming from the cars, and saturated it to the softest of mud almost immediately. About 80% of the entire mass of earth in these two dams was thus deposited as fine mud, and in a few weeks became as solid as the hardest roadway after being traveled over by teams, while about 20% was put in dry at the outer slope. This dry portion constantly absorbed much of the surplus moisture from the adjacent mass of mud, and thus became equally hard and solid.

After their completion, and when the water rose to full height against these dams, they showed no sign of leakage, although a slight settlement occurred at one end of the middle dam, requiring the addition of a small quantity of fresh earth, and the relaying of a limited area of rip-rap thus disturbed.

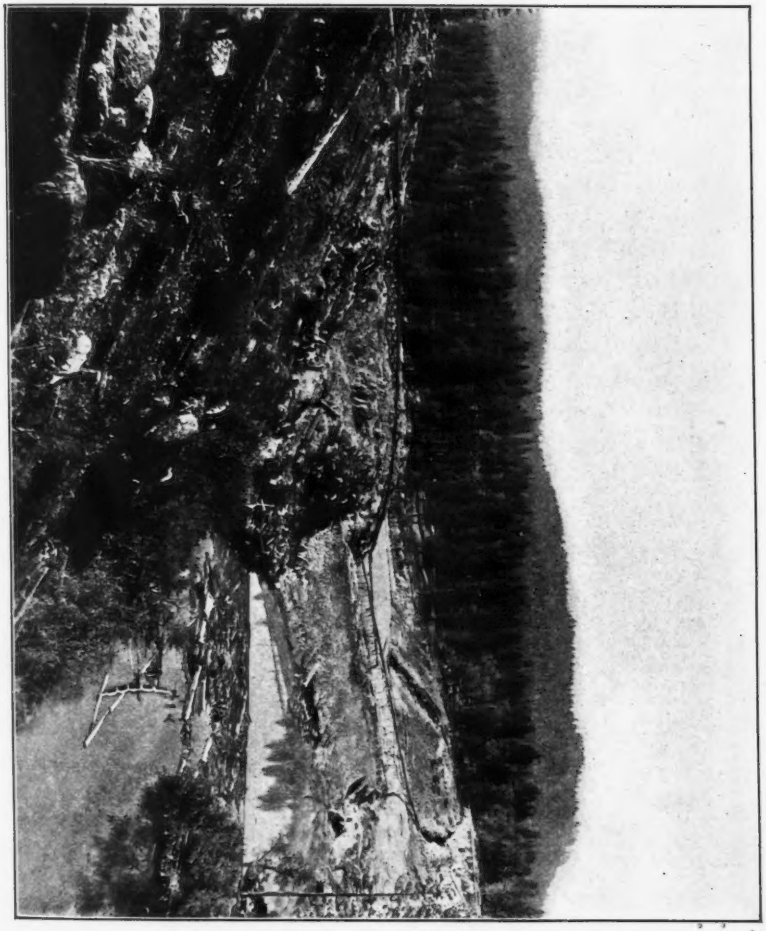
At the North Dam the conditions were somewhat more difficult, and required different methods of operation. This dam was built in the bed of the main stream, where the discharge was from 5 000 to 10 000 cu. ft. per sec. during all the time work was in progress. To take care of the water, a large tunnel was driven at the north end of the South Island, next to the middle dam, and when it was completed the river was forced to go through the tunnel. When

work started on the dam the water was 20 ft. deep in the North Channel. Two parallel embankments of rock, constituting outer toe walls of the rock-fill, were formed across the channel, far enough apart to leave room for sinking a line of timber cribs, 24 ft. wide, placed so that their upper edges were in line with the center core-wall subsequently built. These embankments were formed of large stones dropped from a cableway. Before water was finally admitted into the tunnel (by blowing up the earth coffer-dam in front of it), the embankments referred to had obstructed the flow sufficiently to create a difference of level of 13 ft. above and below the site of the dam. After opening the tunnel this head was reduced several feet, as about 4 000 cu. ft. per sec. passed through the tunnel, while about 1 000 cu. ft. per sec. found their way through the voids in the ridges of rock built across the river channel. When this was accomplished, the velocity in the river bed was so reduced that it was possible for divers to clean off the bed-rock where the timber cribs were to be located, and adjust these cribs to their correct position with reasonable accuracy.

The cribs being loaded with stone, sheet-piling, consisting of 2-in. plank laid double and breaking joints, was placed vertically against the upper face of the cribs and spiked thereto, the bottom of the piling being fitted into a shallow trench excavated by blasting the bed-rock under water. Concrete in bags was carefully placed at the toe of the piling, and was built up against it, about 6 or 8 ft. wide at the base, and 4 ft. or more in height. This constituted the jointing of the piling to the bed-rock below the water line. This work was exceedingly tedious and difficult, and occupied about two months, with two divers, working from September 12th to November 15th, 1904.

The principal part of the hydraulic-filling for the North Dam was delivered from the north side of the river through the flume, in the upper end of which a receiving box was placed where the earth was dumped from wagons into a trap. Water pumped from the river washed it down to the dam. The earth was loaded in the wagons by a modern excavator with belt-conveyors delivering a continuous stream of earth, loosened by plows, to wagons traveling alongside until they received their load. This is an economical device, where the borrow-pit is large and need not be confined to

CRANE VALLEY DAM. GENERAL VIEW FROM LOWER SIDE.



CRANE VALLEY DAM. GENERAL VIEW FROM LOWER SIDE.

narrow limits. The water used was about 1 cu. ft. per sec., delivered by a No. 4 centrifugal pump. The lower end of the flume discharged along the upper side of the wooden core-wall, first filling the voids in the rock-fill and then extending up stream in the water, assuming a very flat slope of 6 or 7 on 1 under the water line. Great difficulty was experienced for some time in stopping a few leaks through the wooden partition, and considerable earth filling was carried through the dam and lost. This may have been due to settlement of the cribs under the weight of rock, or to imperfect joining with the bed-rock. The necessity for doing much of the work in freezing weather was one of the causes of the serious difficulty encountered in making the hydraulic-fill. Layers of frozen earth were formed in the embankment, and these subsequently thawed out when the water was allowed to rise against the dam, creating alarming settlement in the earth next to the rock-fill. This alarm was due to the extent of the disappearance of the earth-fill below the water line along almost the entire length of the dam, and the volume of leakage through the dam, when the water reached its normal height. This leakage was not definitely measured, but it was estimated at one time at more than 6 cu. ft. per sec. In an ordinary earth dam such leakage would necessarily be fatal. In this case it was never a source of actual danger, and only resulted in the loss of 2 000 or 3 000 cu. yd. of earth filling (possibly less), before the leaks were finally closed with fine gravel brought in a barge from a few miles above.

The irrigation system was inaugurated and the dams formally put in service on March 1st, 1905, by the act of closing down the eight huge gates at the tunnel entrance, but it was two or three months later before the North Dam was made secure from leakage, and the earth-fill completed. Since that time the water has stood constantly against the dams, and they have shown no sign of leakage or further settlement, and are in a perfectly satisfactory condition, in which they are likely to remain.

The contract prices for this work were:

Embankment, dry earth .....27.5 cents per cu. yd.
Earth embankment, placed by sluicing.....37.5 " " " "

These prices were necessarily high, on account of the remoteness of the locality, the high cost of fuel, the scarcity of earth in

close proximity, the high price of labor, etc. The prices, however, should have given a handsome profit to the contractors.

The combination rock and earth-fill of the type just described, with a core of wood to serve the temporary function of stopping the flow of liquid earth until it has become solidified, is one which can be recommended unqualifiedly as worthy of imitation and confidence. It is seldom that any earth dam has to be built in a river, or in water of such great depth as 30 ft., and the embarrassing conditions and difficulties encountered must be considered as marking the extreme to which any dam of that height would be subjected.

### An Hawaiian Combination Dam, Recently Finished.

In 1903 the writer was engaged to report on the construction of a dam for the storage of water for the irrigation of sugar cane, on the Island of Oahu, 22 miles from Honolulu. The site is on one of the torrential streams of the island, called the Kaukonahua Gulch, which heads in the Koolau Mountains at an elevation of 2 360 ft. The stream drains from the windward side of the island where the maximum annual rainfall is about 180 in., well distributed through the year. The run-off fluctuates spasmodically between wide extremes, and storage is needed to utilize the stream to any advantage, although its distribution is such that a reservoir of moderate capacity, which will be filled several times each year, will be as serviceable as a much larger reservoir filled less frequently. In this case the average run-off was estimated at about 50 000 acre-ft. per annum, sufficient to fill the reservoir more than six times each year.

The Waialua Sugar Plantation is at the mouth of this stream, and extends up the mountain slopes from sea level to an elevation of about 700 ft. or more. Sugar cane requires an enormous volume of water per acre for irrigation, estimated at a depth of nearly 10 ft. per annum, and this plantation has installed four great pumping stations, by which the greater portion of the water used is supplied from wells near sea level. The aggregate capacity of these pumps is 72 000 000 gal. per 24 hr.; their average lift is from 231 to 540 ft., the extreme lift being 650 ft. The cost of pumping runs into high figures. The fuel bill for irrigation pumping alone was

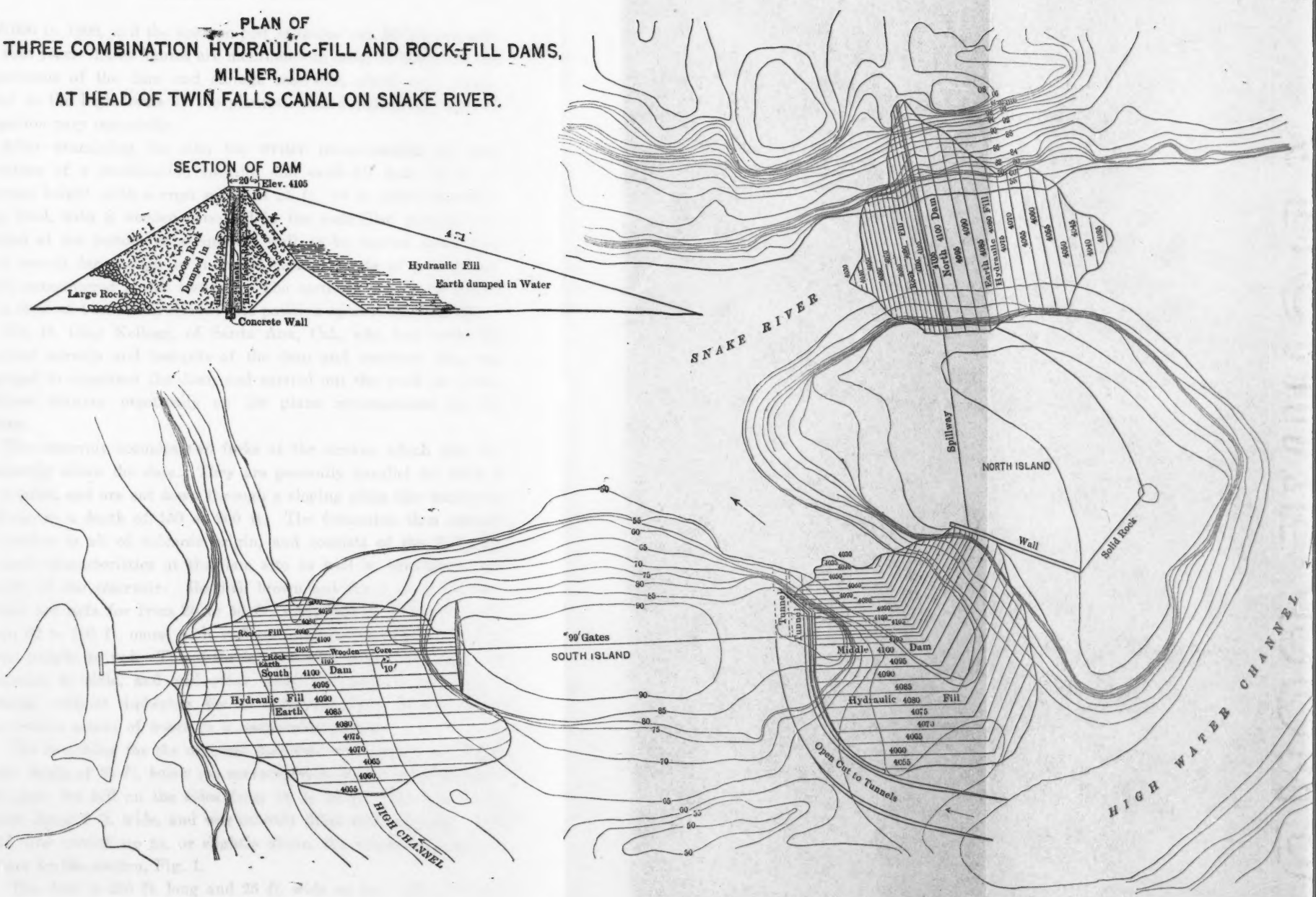
PLAN OF

THREE COMBINATION HYDRAULIC-FILL AND ROCK-FILL DAMS,

MILNER, IDAHO

AT HEAD OF TWIN FALLS CANAL ON SNAKE RIVER.



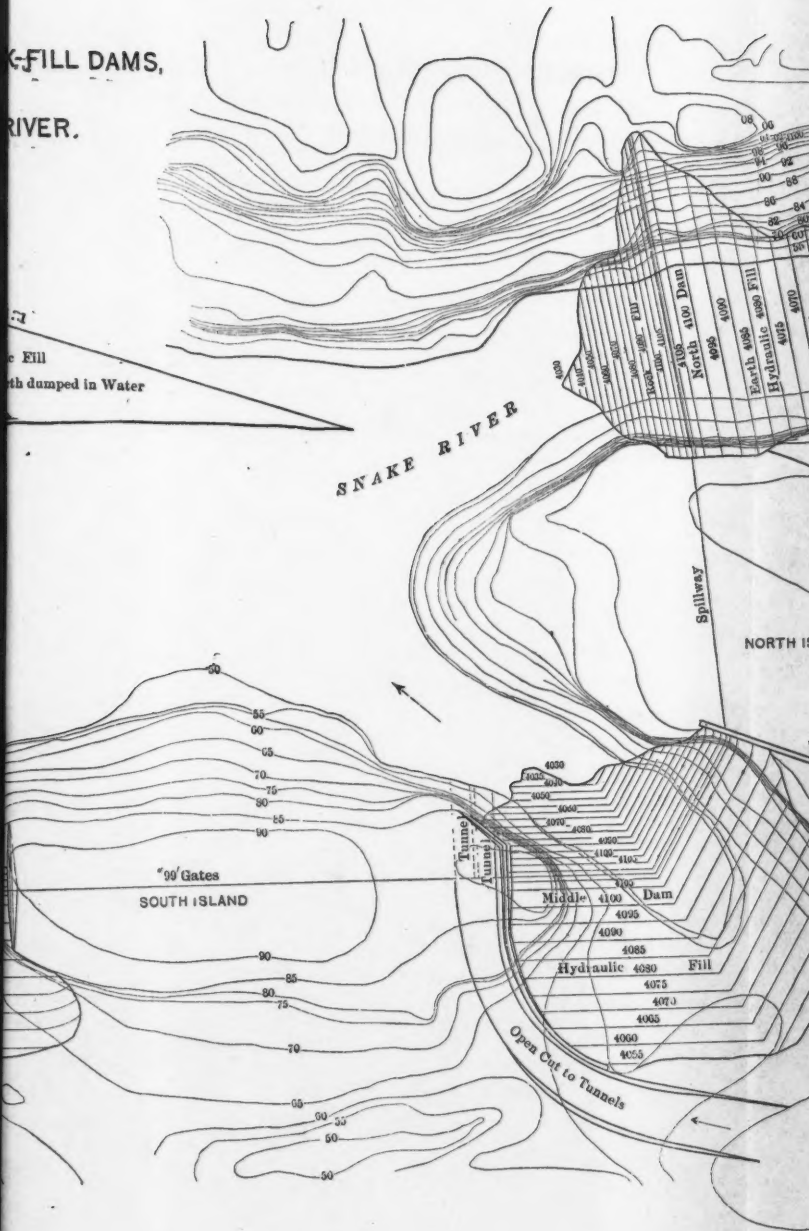
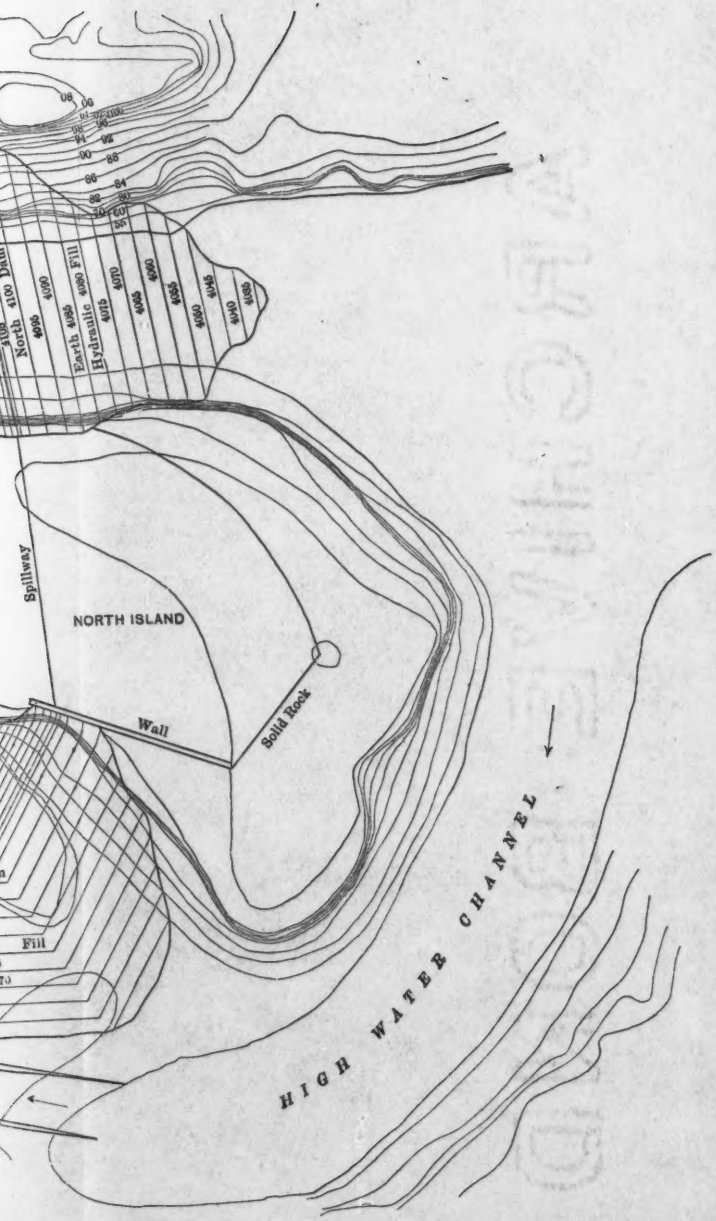

K-FILL DAMS,
RIVER.
e Fill
th dumped in Water
SNAKE RIVER
North 4100 Dam
Earth 4095 Fill
Hydraulic 4095 Fill
Spillway
NORTH IS
"99" Gates
SOUTH ISLAND
Tunnel
Middle 4100 Dam
Hydraulic 4080 Fill
Open Cut to Tunnels

PLATE LXXXVI.
PAPERS, AM. SOC. C. E.
OCTOBER, 1906.
SCHUYLER ON
HYDRAULIC-FILL DAMS.



$180 000 in 1902, and the average cost of water was $63.36 per acre for that year. These figures are mentioned in order to illustrate the importance of the dam and storage reservoir, which will supply water to the high levels of the plantation, and reduce the cost of irrigation very materially.

After examining the site, the writer recommended the construction of a combination rock-fill and earth-fill dam, 98 ft. in extreme height, with a crest width of 25 ft., 10 ft. above the spillway level, with a wooden core-wall in the rock-filled portion, embedded at the bottom in a concrete wall, to be carried down in a deep trench far enough to intercept certain strata of porous material encountered in the test-pits. The earth-fill was to be placed on a slope of 4 on 1, and sluiced into position against the rock-fill.

Mr. H. Clay Kellogg, of Santa Ana, Cal., who had made the original surveys and test-pits of the dam and reservoir site, was engaged to construct the dam, and carried out the work in a very efficient manner practically on the plans recommended by the writer.

The reservoir occupies two forks of the stream, which join immediately above the dam. They are generally parallel for some 5 or 6 miles, and are cut down through a sloping plain like miniature cañons, to a depth of 150 or 200 ft. The formation thus exposed in section is all of volcanic origin, and consists of the following general characteristics at the dam site as well as throughout the length of the reservoir: Reddish brown soil for 2 or 3 ft., then bright red tufa for from 20 to 50 ft., underlaid by yellow tufa for from 50 to 100 ft. more, with various intermediate shades of color, from purple to red. This tufa is generally quite free from any tendency to slide, and will often stand vertically in trenches or tunnels, without timbering, for an indefinite time. It also resists the erosive action of water in a remarkable manner.

The trenching for the concrete core-wall was carried to a maximum depth of 38 ft. below the surface, while it was extended laterally into the hill on the sides from 14 to 28 ft. The trench was made about 5 ft. wide, and was entirely filled with concrete. This wall was carried up to, or slightly above, the original surface, as shown by the section, Fig. 1.

The dam is 460 ft. long and 25 ft. wide on top, with a base of

580 ft. up and down stream, Fig. 2. The rock-fill has a base of 80 ft., and is 11.5 ft. thick at the top, containing 26 000 cu. yd., a considerable portion of which is laid up as a dry wall by hand, the outer slope being $\frac{3}{4}$ to 1, and the inner side vertical. The wooden core-wall is 2 ft. below the upper face of the rock-fill (down stream) and consists of double 2-in. redwood plank, laid horizontally and spiked to 3 by 6-in. uprights, placed 2 ft. apart, from center to center, with a double layer of burlap dipped in hot asphaltum between the two layers of plank.

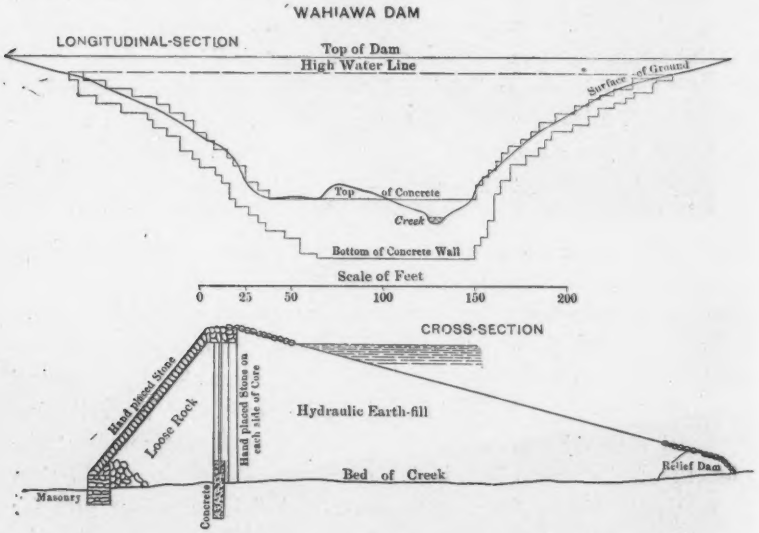



FIG. 1.

The rock was brought to the site by cars from a distance ranging from 1 to 6 miles, and dumped from a high trestle built along the longitudinal axis of the dam. It is basalt, found in the stream beds in boulders of all sizes. Many of these boulders required to be blasted for handling.

Water for sluicing was delivered by pipes from an upper ditch to a point about 2 000 ft. distant, and 50 ft. higher than the dam. Between this point of delivery and the dam was a body of earth of great depth which was considered suitable for the embankment. The ground-sluicing method was used, as the head available was insufficient to give the necessary velocity for mining and disinte-

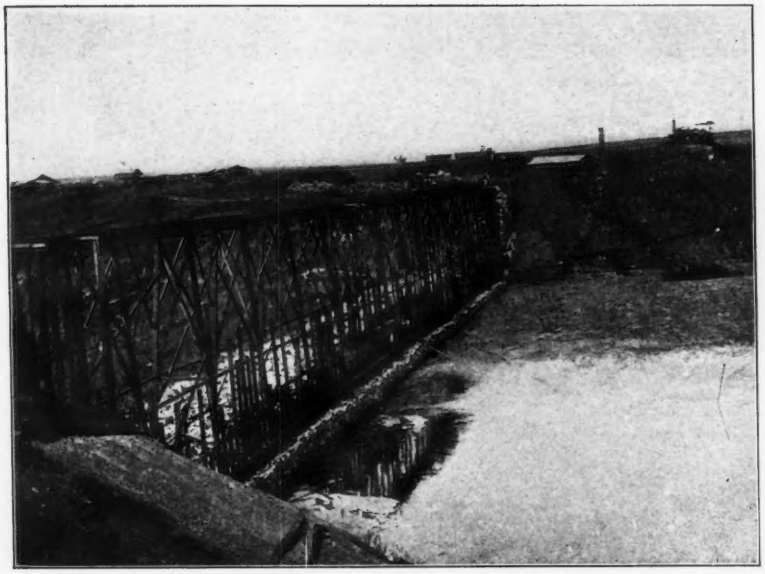


FIG. 1.—WAIALUA DAM, SHOWING HYDRAULIC FILL BEING SLUICED IN AGAINST THE ROCK-FILL.



FIG. 2.—WAIALUA DAM SITE, LOOKING DOWN STREAM. SHOWING THE GORGE FILLED BY THE DAM.

Mitoli

Fig. 2.

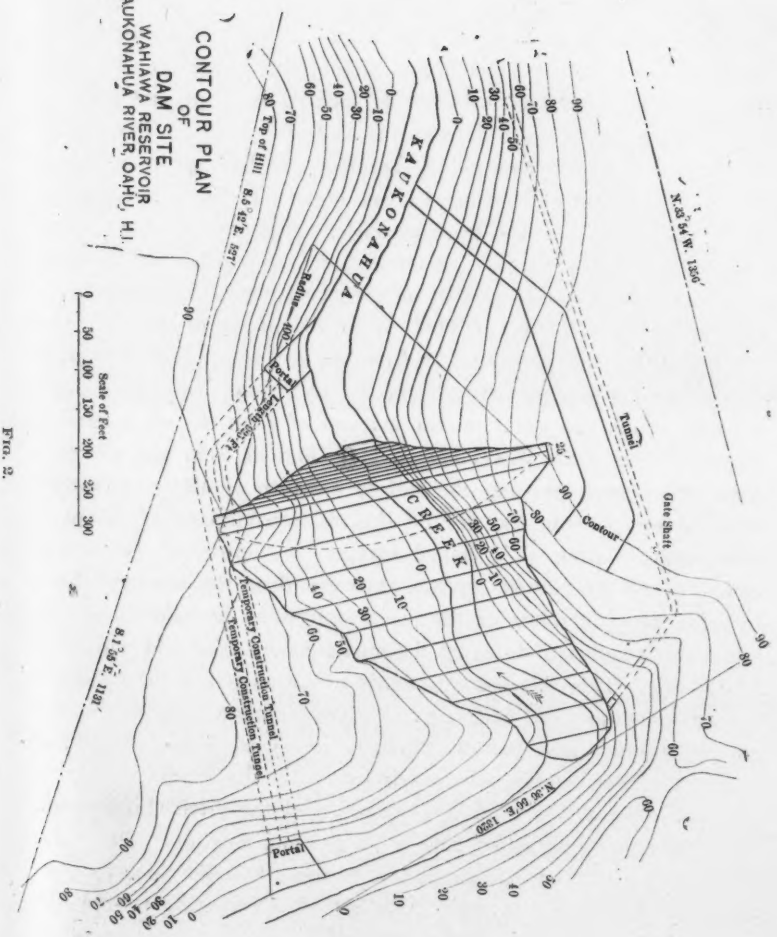

CONTOUR PLAN
OF
DAM SITE
WAHIAWA RESERVOIR
KAUKONAHUA RIVER, OAHU, H.I.
KAUKONAHUA
CREEK
Tunnel
Gate Shaft
Contour
Portal
Radius 600'
Top of Hill
Temporary Construction Tunnel
Scale of Feet
0 50 100 150 200 250 300
N. 35° 54' W. 1356'
N. 30° 06' E. 1320'
S. 8.4° E. 827'
S. 81° 36' E. 1187'

FIG. 2.

grating the material by the hydraulic monitor. Ordinary soils can be washed very readily by flowing water over it if sufficient velocity is given, and usually very moderate grades have to be given to irrigation ditches to prevent them from cutting their beds and forming deep miniature cañons. This volcanic tufa of Hawaii, however, contains a large amount of iron oxide, and sufficient structural cohesion to make it exceedingly difficult to sluice, even when plowed, chiefly because it is totally lacking in sand and grit, or any cutting substance to furnish the tools for erosion. Strange to say, the tufa, while resembling the clay, and having an unctuous feeling to the touch, settled in the pond very rapidly, and the water flowing away at the drainage outlet was generally clear enough to drink. This is a most interesting and remarkable fact, which is without precedent or parallel in the experience of the writer.

The method finally adopted to move the earth through the sluices to the dam was to dig a ditch about 4 ft. deep at the upper end, and from 12 to 16 ft. deep at the lower end next to the dam, through which the water, to the amount of 8 cu. ft. per sec., was turned. This ditch was 1 300 ft. long, and at each end a steam plow was placed, plowing the soil to a width of 12 ft. on either side. After plowing the ground the traction engines of the plow were used to drag a V-shaped scraper, or "crowder" as it was called, along the plowed surface, thus crowding the loosened earth into the running water of the ditch alongside, the velocity of the water being sufficient to carry the load thus received and deliver it to the dam. This was the only effective means found for handling the earth, as the water had no effect whatever when turned upon the plowed ground, and merely ran over it clear, without washing it away. This process was continued until the ditch grade was reached, when a new strip was plowed, and the ditch shifted over to the bluff bank on either side of its original position. This work of loosening and delivering the soil to the ditch was done by contract for 8 cents per cu. yd. The cost of distributing it properly averaged 3 cents per cu. yd., a total of 11 cents per cu. yd. The total volume of the earth-fill was 141 000 cu. yd., of which 100 000 cu. yd. were put in by aid of the four steam plows used for plowing and crowding; the remainder was loosened by hand work, blasting, and picking and shoveling into the ditches. The total cost of the

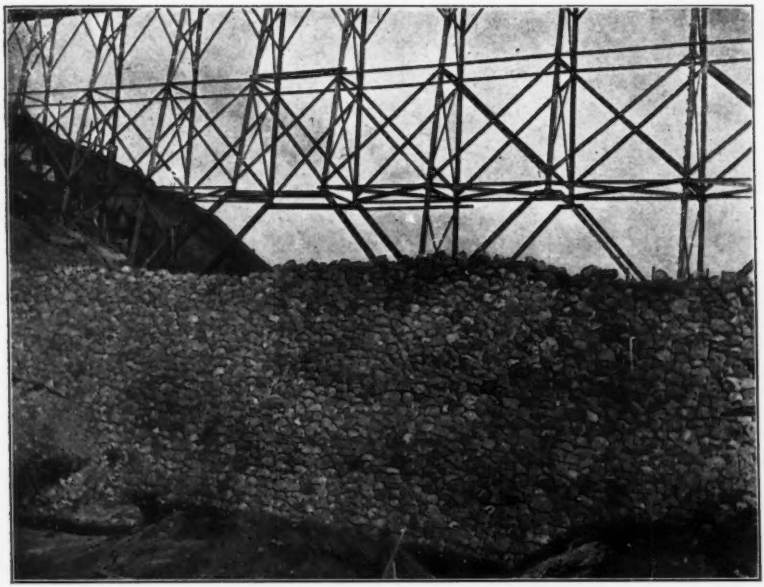


FIG. 1.—ROCK-FILL ON DOWN-STREAM SIDE OF WAIALUA DAM.

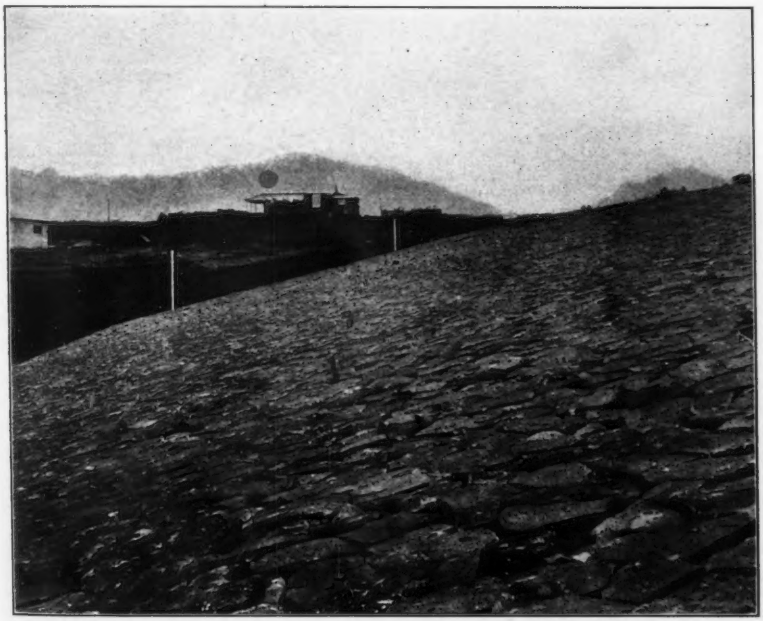


FIG. 2.—RIP-RAP ON FACE OF HYDRAULIC-FILL, WAIALUA DAM.

dam was $281 000, including a diverting or relief dam, 29 ft. high, four long tunnels around the dam, the regulating-gate tower, 48-in. outlet pipe, etc. The hydraulic-fill is reported to be very hard, solid and entirely water-tight, and the dam is a satisfactory one in every way, which is gratifying to all concerned, as the situation presented grave difficulties.

The elevation of the spillway of the dam is 844 ft. above sea level. It commands all lands below 700 ft. elevation in the Waialua Plantation, and will be used to irrigate lands between the 400 and 700-ft. levels. This reservoir is expected to effect the irrigation of 3 500 acres, at a saving of not less than $50 per acre per annum. If this expectation is realized, the cost of the dam will be covered in two years. The reservoir has a capacity of 2 500 000 000 gal., or 7 800 acre-ft.

The construction of the dam is illustrated by the photographs on Plates LXXXVII and LXXXVIII.

### A Combination Dam in New Mexico.

The United States Indian Bureau is engaged in building a dam for the storage of water on the Zuñi River for the purpose of irrigating the lands of the Zuñi Indian Reservation, in McKinley County, New Mexico, about 40 miles south of Gallup. J. B. Harper, M. Am. Soc. C. E., whose title is Superintendent of Irrigation, is the Engineer-in-Charge, and the writer is Consulting Engineer. Mr. W. H. Code, Inspecting Engineer of the Indian Bureau, has also collaborated on the plans, with valuable suggestions.

The dam when completed will be 720 ft. long on top, 70 ft. in height, and will consist of a loose-rock embankment, backed by an earth-fill, Fig. 3 and Plate XC. The rock-fill is being carefully hand-laid on the top slopes, with loose rock well chinked. The down-stream slope of the rock is 1¼ on 1, stepped in regular benches, while the up-stream slope is ½ on 1, the cubic contents being 32 400 cu. yd. The base is thus about 125 ft. Plate LXXXIX shows the upper and lower faces of the rock-fill as they appeared in January, 1906.

The hydraulic-fill is to have a slope of 3 on 1. The crest width will be 20 ft., with vertical parapet walls, 5 ft. in height on each

side below the crest. Its cubic contents will be 51 300 cu. yd. No core-wall is to be built in the dam, but the liquid earth to be sluiced in position will be held in place between levees of dry earth hauled with teams. Against the face of the rock wall a dry bank about 10 ft. wide will be built up a few feet in advance of the rising pond of mud to keep the liquid earth from penetrating the rock-fill and escaping through the voids, while on the up-stream slope a similar bank will be built. The stream will be carried through the outlet tunnel while sluicing is in progress.

A steam pump with a capacity of about 3 cu. ft. per sec. has been provided, and water will be delivered, through an 8-in. pipe

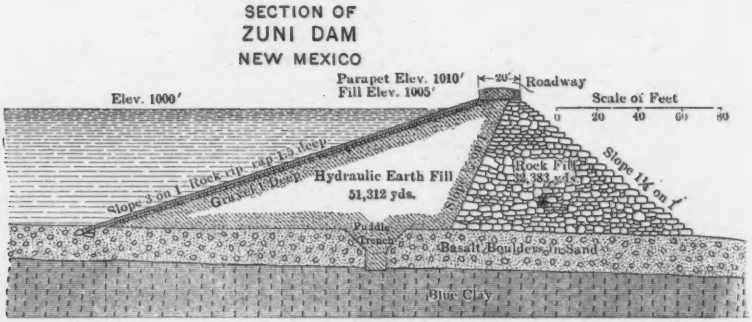



FIG. 3.

to a hydraulic giant, with ample pressure to give a cutting stream, sufficient to loosen the soil and convey it through the sluice-boxes from the borrow-pits on the north side of the cañon to the dam.

A mechanical analysis of the soil available for the hydraulic-fill, made by the writer, showed that it contains 73% of sand and 27% of clay. The sand was found to have an exceedingly fine texture, 99% passing through a 30-mesh sieve, having 900 holes per sq. in. These materials are considered to be extremely favorable for the purpose, and will not only be readily disintegrated with a hydraulic stream of moderate force, but will flow readily and without clogging in the flume on a grade of 3%, and, after settlement in the bank, will form a dense embankment, of great solidity,

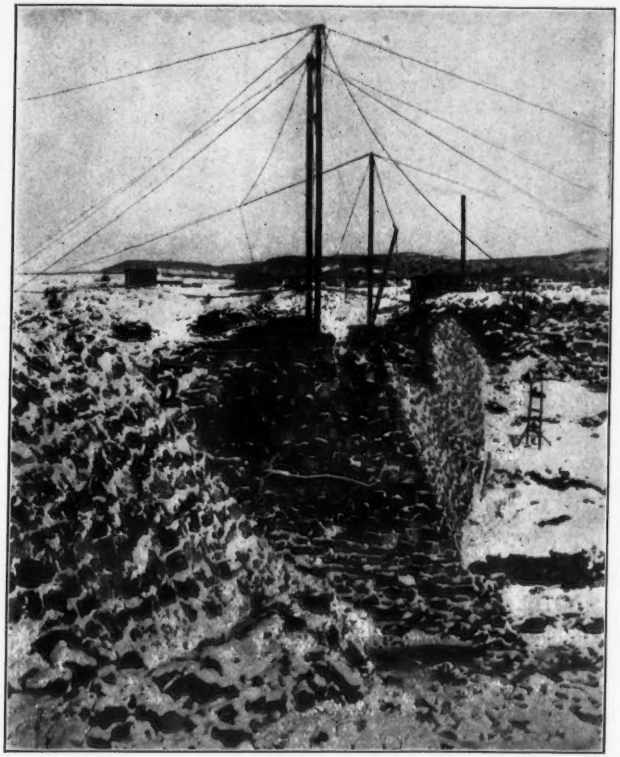


FIG. 1.—ZUNI DAM, LOOKING NORTH ALONG UP-STREAM FACE OF ROCK-FILL, AGAINST WHICH THE HYDRAULIC-FILL IS TO BE BUILT.

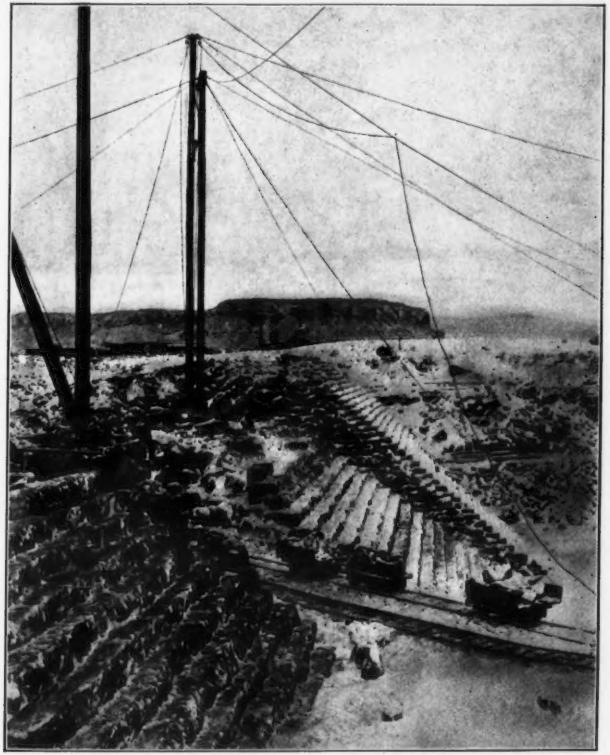


FIG. 2.—ZUNI DAM, LOOKING SOUTH ALONG DOWN-STREAM SLOPE, SHOWING HAND-LAID DRY WALL.

the voids in which will be entirely filled by the contained clay. It will thus be impervious to water and constitute a safe dam. The extreme elevation of the borrow-pit will be 35 ft. higher than the top of the dam. Assuming a pressure of 100 lb. per sq. in. at the nozzle of the giant, the total lift, including friction in the pipe, will be equal to a static head of 330 ft. The plant will require about 100 h. p., and the cost for power is estimated at from 2 to 4 cents per cu. yd. The fuel to be used is obtained from a coal mine opened by Mr. Harper on the Reservation a few miles above the dam.

The reservoir will have a capacity of 16 000 acre-ft., covering an area of 623 acres, nearly circular in shape. It intercepts the drainage from 650 sq. miles, and is expected to fill ordinarily once each year, from the usual rainfall and run-off. It is hoped to accomplish the irrigation of from 5 000 to 10 000 acres, and bring prosperity to an interesting tribe of Pueblo Indians.

The work is being done chiefly with Indian labor, but under many difficulties and with many interruptions, due to the numerous religious festivals which these curious people observe, during which they suspend all work. It is expected that the dam will be completed during 1906. An appropriation of $85 000 is being expended on the construction.

### Terrace Dam, Alamosa River, Colorado.

The highest hydraulic-fill dam yet projected in the United States is under construction in Southwestern Colorado, for the storage of water for irrigation. The location is at the head of the lower cañon of the Alamoso River, a few miles above the point where the river enters the San Luis Valley. The situation is quite unique, inasmuch as the lower 70 ft. of the dam is a narrow slit in the bed-rock, from 20 to 60 ft. wide, where the river has cut its way down through a ledge of hard trachyte, forming a cañon with vertical side walls. Above this ledge the section across the cañon has a bowl-shaped form like the end of an ellipse. The dam has been projected to the ultimate height of 180 ft. above the river bed in the bottom of the cañon, or about 110 ft. above the valley proper. The length of the dam at the height of 180 ft. will be about 500 ft. The crest width, 10 ft. above the water line, or spillway

level, will be 20 ft.; the up-stream slope being 3 on 1, and the down-stream slope 2 on 1. The plan and sections are shown in Figs. 4 and 5. The capacity of the reservoir at the 170-ft. level is about 18 000 acre-ft., of which only 6% is in the lower 70 ft., and 10% is in the upper 5-ft. layer.

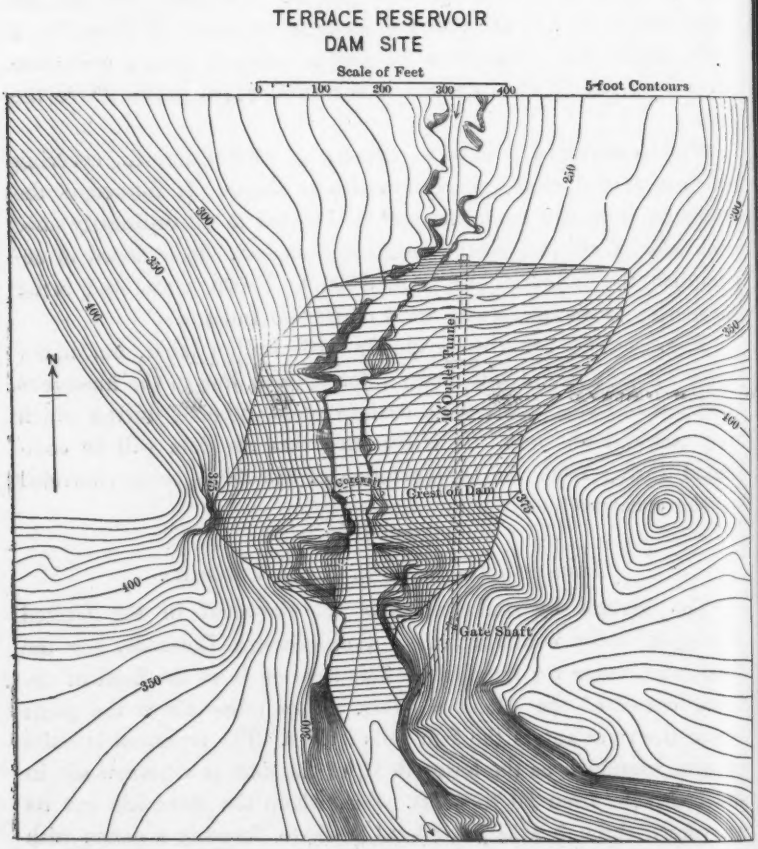
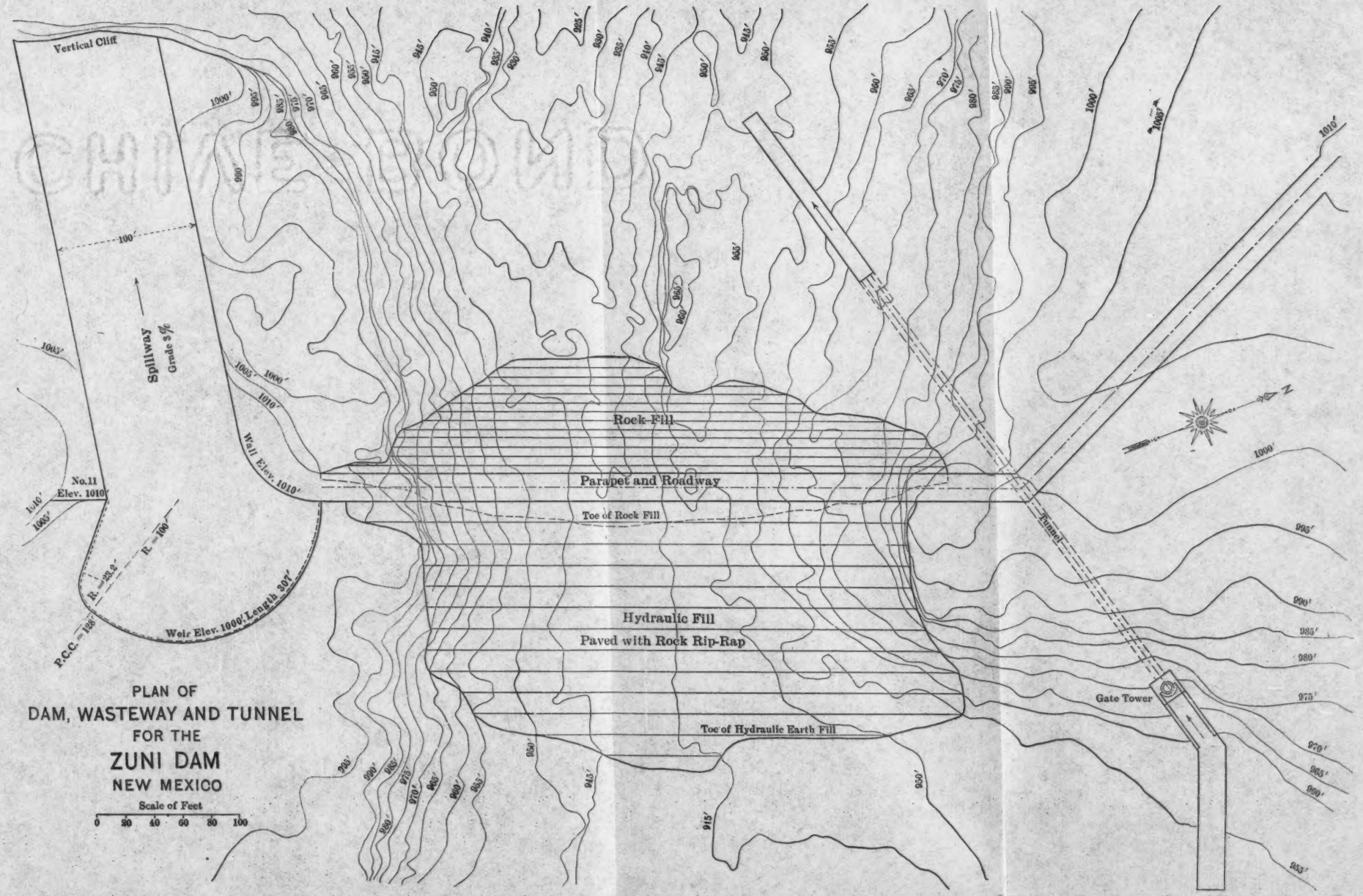



FIG. 4.

There are ample evidences that the valley to be occupied by the reservoir was once a lake, which was carved out of the mountains by glacial action. A gap in the rim of the reservoir, to the north of the dam exhibits a great mass of glacial drift deposited as a lateral moraine, and consisting of sand, gravel and boulders, with

PLATE XC.
PAPERS, AM. SOC. C. E.
OCTOBER, 1906.
SCHUYLER ON
HYDRAULIC-FILL DAMS.




PLAN OF
DAM, WASTEWAY AND TUNNEL
FOR THE
ZUNI DAM
NEW MEXICO

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an intermingling of clay. This is sufficiently convenient to be used for sluicing into the dam. On the south side the trachyte has decomposed and disintegrated to considerable depth, yielding excellent material for hydraulic filling, as the portion that is loose enough to be moved by the hydraulic giant is composed of spawls and splinters of hard rock, intermingled with clay and loam.

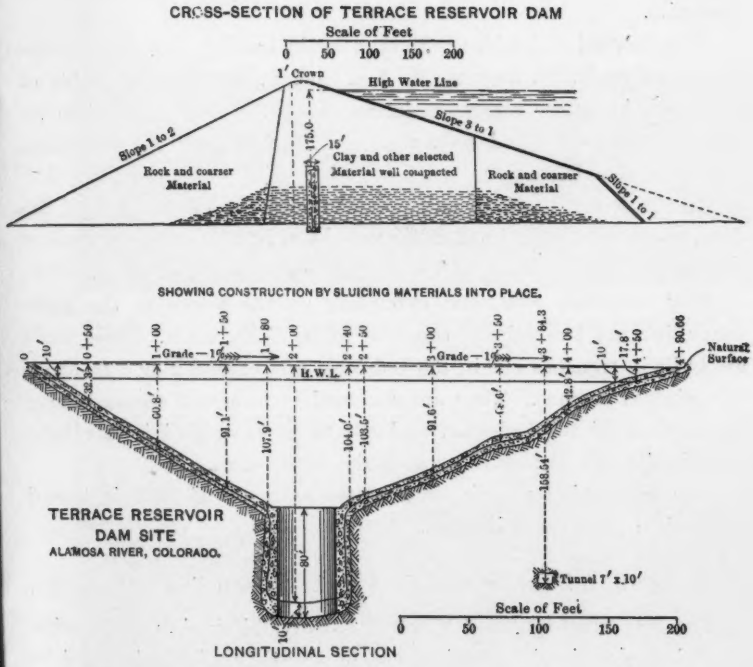



FIG. 5.

A ditch and flume, Fig. 1, Plate XCI, 5 miles in length, has been built from the Alamosa River, taken out at a point above the reservoir at sufficient elevation to deliver water about 200 ft. higher than the top of the dam. This ditch was completed too late in the fall of 1905 to begin sluicing, but as soon as spring opens in 1906 it is expected that the work will begin by ground-sluicing and hydraulic mining at both ends of the dam. The dam is being built

by contract for 18 cents per cu. yd. A tunnel, 725 ft. long, 7 ft. high, and 10 ft. wide, has been excavated for carrying the stream during construction and as an outlet to the reservoir. The outlet gates will be operated from a shaft, 75 ft. deep, sunk through the solid rock to the tunnel, at a point about 200 ft. down stream from the crest of the dam. The engineer in charge of the work is Mr. E. W. Case, of Colorado Springs, Fig. 2, Plate XCI, and Figs. 1 and 2, Plate XCII, illustrate the situation at this remarkable dam site.

The method of building the dam by hydraulic sluicing was first suggested by T. W. Jaycox, M. Am. Soc. C. E., State Engineer of Colorado, by whose recommendation the writer was engaged to report upon the plans and make such modification as, in his judgment, seemed desirable.

In the lower 70 ft. of cañon section, on the center line of the dam, a concrete wall, 15 ft. thick, has been built, curved on a short radius of 50 ft., to serve as a core-wall to the height of 70 ft. Connecting with this wall, and extending up the slopes to the high-water line, are two parallel concrete walls, 25 ft. apart. These walls are built in trenches cut in the bed-rock, and extend 2 or 3 ft. above the original surface. They are designed to intercept seepage along the surface of the bed-rock, and are to be enveloped in the body of sluiced earth or clay composing the center core.

The completion of this dam in the summer of 1906 is looked forward to with great interest.

### Hydraulic-Fill Dams of the Mexican Light and Power Company.

The Mexican Light and Power Company, Limited, a corporation supplying electric light and power to the City of Mexico and to surrounding towns, is constructing four dams by the hydraulic process, on the Necaxa and Tenango Rivers, about 100 miles northeast of the National Capital, two of which are to be 175 and 190 ft. in height, respectively, and of unusually large volume. All these works are under the general direction of F. S. Pearson, M. Am. Soc. C. E., who is Vice-President and Consulting Engineer of the Company. Albert Carr, M. Am. Soc. C. E., is Manager of Construction, and Mr. F. S. Hyde is Resident Hydraulic Engineer. The responsibility for recommending this type of dam for these



FIG. 1.—FLUME UNDER CONSTRUCTION FOR CARRYING WATER FOR SLUICING OPERATIONS ON TERRACE DAM.



FIG. 2.—TERRACE DAM. CONCRETE CORE-WALL UNDER CONSTRUCTION.

huge embankments rests with the writer, who was called upon in January, 1905, to report on the subject, and has since been retained as Consulting Engineer to supervise their construction. His reasons for recommending the hydraulic-fill were, briefly, that in his judgment the foundations as exposed by test-pits over the dam site and as shown in the outlet tunnel of the reservoir at Dam No. 2, which had pierced the hill against which one end of the dam is to rest, are unsuitable for supporting a high masonry dam such as had been projected, although sufficiently stable and entirely satisfactory as a base for an earthen dam. Earth dams of the ordinary type, if made of great height, involve the handling of such enormous masses of earth as to become prohibitive in cost, and therefore, up to the present date, the limit of height of earth dams has been about 130 ft. Where earth filling costs from 50 to 80 cents, and clay puddle from $1 to $2 per cu. yd., when selected, spread, sprinkled and rolled with the extreme care needed in high earth dams, it is evident that the capital invested becomes too great, in ordinary situations, to warrant the risk of building earth dams by the ordinary methods much beyond the limit of 120 or 130 ft. In reality, there is no more reason why an earth dam, if it can be built at sufficiently moderate cost to justify the expense, should not be 250 to 300 ft. in height, provided the materials used are suitable, are placed with sufficient care, and it is of such massive proportions as to afford an ample factor of safety.

In the case of Dam No. 2, at Necaxa, a high dam was required in order to afford the desired storage for equalizing the stream, and to waste as little water as possible. As between an earth dam of the ordinary type and a hydraulic-fill for this situation, there was no comparison, either in cost, length of time needed for construction, or in stability and security when finished, every condition being in favor of the latter. Fortunately, there is right at hand, at convenient distance and proper elevation, a sufficient mass of broken limestone, intermingled with pure yellow clay, to build the dam of any height desired, with the use of streams of water under high pressure brought to the site by a ditch. The proportions of rock and clay are about equal, and the separation of the two materials by water, depositing the rock on the outer side and the clay in the center, will manifestly make an embankment more

stable and secure than could have been made with the earth which was available, and at far less cost and in shorter time.

The volume in Dam No. 2, when finished, will be 1 525 000 cu. m. (1 993 700 cu. yd.), and the dimensions as follows:

| | |
|---|---|
| Length on top | 1 220 ft. |
| Height above lower toe | 190 " |
| Height above upper toe | 178 " |
| Down-stream slope | 2 on 1 |
| Up-stream slope | 3 on 1 |
| Width of crest | 16.5 m. = 54 ft. |
| Base, measured along stream bed | 975 " |

The ditch for water supply for sluicing is 17.5 km. long, and delivers water for building Dam No. 3 as well as Dam No. 2, the former being on the same stream and about 6 miles above No. 2. The ditch is of sufficient capacity to deliver 70 cu. ft. per sec. to Dam No. 3, and 53 cu. ft. per sec. thence to Dam No. 2. The height of the ditch above the base of Dam No. 2 at its point of delivery is 728 ft. This will give an effective head for mining the material, at the successive levels opened out for delivery, from the base to the crest of dam. Plate XCVI shows the general plan of the dam, and the photographs on Plate XCV illustrate the location of the dam, and the excavation for the core-wall, etc. The material will all come from one side at both dams.

The plan of operation proposed at each of these dams is to build up the base to a height of 50 ft. by delivering material through pipes supported on trestles. These will be built parallel to the center lines on each side, and at a convenient distance back from the toe of the slope, in order to permit of delivery to the slopes with the shortest possible side flumes. The lower 25 or 30 ft. will require delivery from one side of the flume, until the slope reaches a point beneath the trestle, when the side flumes will be reversed, delivering toward the center of the dam until the limit of height of the first trestle is reached.

Thus the trestles will project out of the slopes on either side. From about the 50-ft. level to the top it is planned to deliver sluiced materials through flexible-jointed pipes supported on pontoons floating in the pond maintained on top of the dam. The stream of tailings from the pipe will be distributed evenly



FIG. 1.—UP-STREAM SIDE, CONCRETE CORE-WALL TERRACE DAM.



FIG. 2.—LOOKING UP STREAM THROUGH THE GORGE IN WHICH THE TERRACE DAM IS BEING BUILT.

along or near the line of the slope, first on one side and then on the other, thus building up 2 or 3 ft. in height in a continuous "windrow" or levee. The larger stones contained in the material will be raked out and laid by hand on the slopes, forming faces of dry rock wall. At Dam No. 2 it is expected that the proportion of rock in the borrow-pit will be so large that very little additional rock will have to be provided by mechanical means to maintain the slopes properly. Fig. 6 shows a cross-section of Dam No. 2.

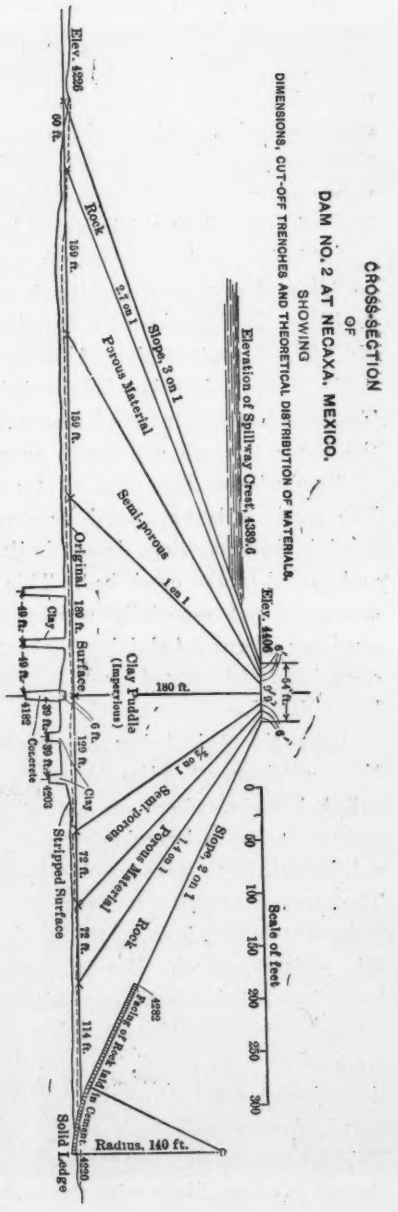



Fig. 6.

The spillway excavation will be made with one of two hydraulic giants to be installed. The material in the spillway gap is chiefly clay, without sand or rock. The maximum depth of excavation for the spillway will be more than 100 ft. The other giant will work in a borrow-pit where loose rock predominates. The two streams of material can be directed and combined in any desired proportion, and rock and clay can be mixed from either pit at the head of each of the two pipe lines delivering material to the dam.

At Dam No. 3, conditions are somewhat different, and the comparative scarcity of loose rock in the clay bed to be used as the principal borrow-pit may make it necessary to bring rock by other mechanical means to fill out the slopes with the desired quantity of stable material. It is not intended that at either dam shall there be the slighest possible chance for a sloughing of the slopes, or an outward movement of the mass during construction by reason of a lack of a sufficient thickness of large rock to give ample drainage and friction, and consequently ample stability, for the slopes will be flatter than the natural rough angle of repose of such rock. Fig. 2, Plate XCV shows the foundation of Dam No. 3, and Plate XCVII is a contour plan of the site.

Dam No. 1 is a low barrier being built by the company on the Tenango River, a parallel stream. It is to be used for diverting the water through a 3 000-ft. tunnel, into the Necaxa River, immediately below Dam No. 3. Its maximum height is about 30 ft. The earth is being placed by ground-sluicing from a ditch, and filled in between slope levees built up by hand from the boulders and gravel of the creek bed. This is a comparatively unimportant structure, not especially worthy of further notice, except as a specimen of ground-sluicing without water under pressure. Its construction is illustrated by Figs. 1 and 2, Plate XCIII and Fig. 1, Plate XCIV.

Dam No. 4 is being constructed near the headwaters of the Necaxa River, 25 miles above the Village of Necaxa, at a place called Laguna, where an extensive reservoir is being formed to store water to be brought from an adjoining stream by a long tunnel, as well as to store surplus water from its own local water-shed. The storage capacity is about 2 500 000 000 cu. ft. The dam will be about 2 880 ft. long on top, 80 ft. maximum height, and will contain 400 000 cu. yd. For temporary storage, the upper toe of the large dam is being built to a height of 40 ft., as a combination rock-fill and earth embankment, with a core-wall of plank, backed by a layer of clay, 10 ft. thick, carefully placed against it on the upper side. The lower half of the dam below the plank core-wall is composed of loose rock to a height of 40 ft., for temporary storage. This will form an integral part of the larger dam, which will be sluiced in place chiefly with the hydraulic monitor. It will be neces-

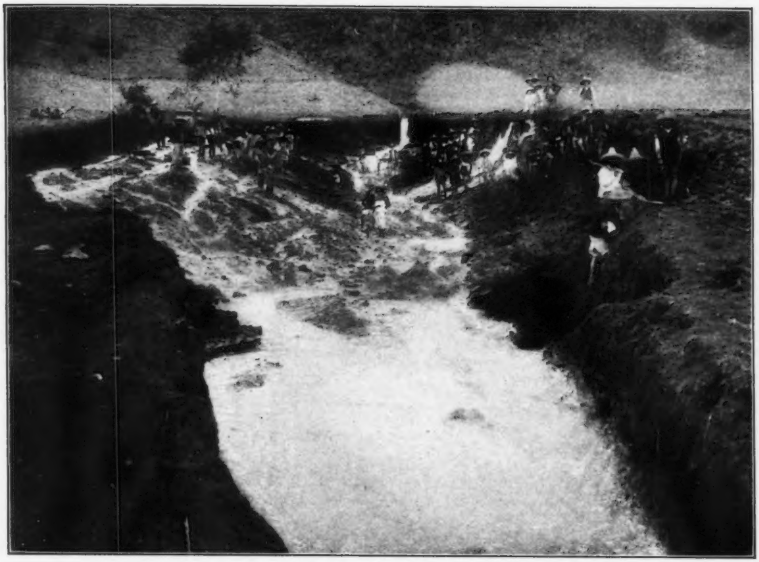


FIG. 1.—GROUND-SLUICING ON DAM NO. 1, TENANGO RIVER.



FIG. 2.—METHOD OF DISTRIBUTING SLUICED MATERIALS THROUGH PIPES, DAM NO. 1, TENANGO RIVER.

sary to pump the water for this work, and an installation, similar to that used at Lake Frances Dam, has been planned for this purpose. The elevation at the base of the dam is 2 144 m. (7 032 ft.) above sea level. It is planned to draw water from this reservoir, after the larger dam is built, through a tunnel about 1 500 ft. long, discharging into the adjoining basin of Los Reyes River on the north. About 2 miles down stream from this tunnel a fifth dam is planned in the narrow gorge of Los Reyes River, where similar methods of construction will probably be used. A conduit about 5 miles long will lead from Los Reyes Reservoir to the head of a power drop, where a fall of 2 380 ft. to the level of Reservoir No. 3 is to be utilized for a second installation, where 100 000 h. p. will be developed in the near future with the auxiliary supply to be diverted from adjoining water-sheds into Reservoirs Nos. 4 and 5, as described .

### Projected Hydraulic-Fill Dam on Wichita River, Texas.

An earth dam, 3 000 ft. long on the crest and 80 ft. high, above the river bed, has been projected on the Wichita River, some 50 miles above the City of Wichita Falls, Texas, to be sluiced in place with water pumped from the river. The dam will create a reservoir covering about 10 000 acres, and store about 280 000 acre-ft., to be used for irrigation in the fertile Red River Valley. Borings have shown the existence of a heavy bed of blue and red clay, in the river valley at the dam site, at a maximum depth of 20 ft., overlaid by a stratum of quicksand. As the clay extends up the sides above the water line, the sand stratum is confined to the channel. It is proposed to drive steel sheet-piling across the stream at the center line of the dam to serve as a cut-off for this quicksand layer, and avoid the excavation of the base to the shale bed-rock. The steel piling can be driven into the clay, and will form an impervious barrier to the underflow in the overlying sand. The piles will be allowed to project upward a few feet into the hydraulic-fill, and be enveloped in it.

The earth to be used for building the dam is a red, sandy soil, with a large percentage of clay intermingled with sand and gravel. The top, or surface layer, of the plains above the crest level of the dam, contains an abundant quantity of hard rock nodules of the

general sizes of river gravel, but with enough angular protuberances and cavities to show that it was not water-borne, but is the hard residuum of disintegrated rock, which has melted and been carried away as clay or sand, or remains in place as surface soil.

Plans for this dam have been submitted by the writer, and approved by the promoter of the enterprise.

### Hydraulic-Fill Dam in Brazil.

The São Paulo Tramway, Light and Power Company, Limited, has a power plant on the Tieté River, in the State of São Paulo, Brazil, 22 miles below the thriving city of São Paulo, where 15 000 h. p. is generated and transmitted to the city. To equalize the flood flow, and make up for shortage in dry seasons, the company is constructing a dam 14 miles above the city, on a branch of the river known as the M'Boy Guassu. The dam will be about 2 000 ft. in length, and from 40 to 45 ft. high, forming a reservoir covering an area of about 5 000 acres, and storing approximately 100 000 acre-ft. of water. The plan proposed contemplates the driving of a row of sheet-piles, from 20 to 30 ft. below the surface in the center of the dam. Steel piles will be used for the river channel, and tongued and grooved wooden piles for the remaining distance. The sod and surface soil to the depth of 2 ft. will be stripped from the base of the dam and built in the form of a levee at each slope footing. Between these levees earth will be sluiced from a hill at one end of the dam, through a flume and pipe laid on a trestle with a grade of 3% from the hillside to within 300 or 400 ft. of the extreme end. This trestle will be built on the center line to the full height required to complete the dam without further addition. It will be 75 ft. in maximum height. Lateral flumes will extend to the slopes on each side at intervals of 50 ft. The materials consist of disintegrated granite, containing a sufficient admixture of clay to yield a water-tight material for the core, and give sufficient coarse, porous and gritty material for the slopes to enable them to have the required friction to stand where placed without sloughing down to flatter angles of repose. The disintegration of the surface rock has left a solid bed of red and gray clay covering the surface to a depth of from 5 to 15 ft., but in the interior of the

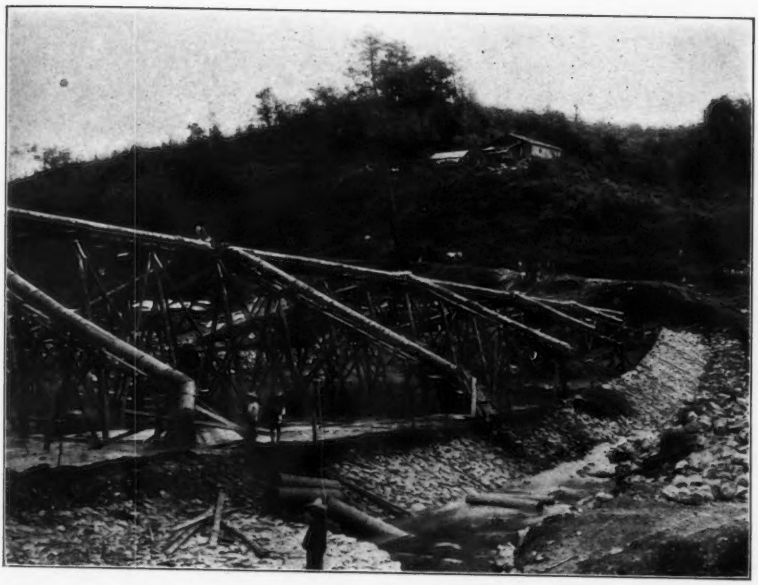


FIG. 1.—LIQUID EARTH BEING DEPOSITED THROUGH PIPES ON OUTER SLOPES OF DAM NO. 1, TENANGO RIVER.

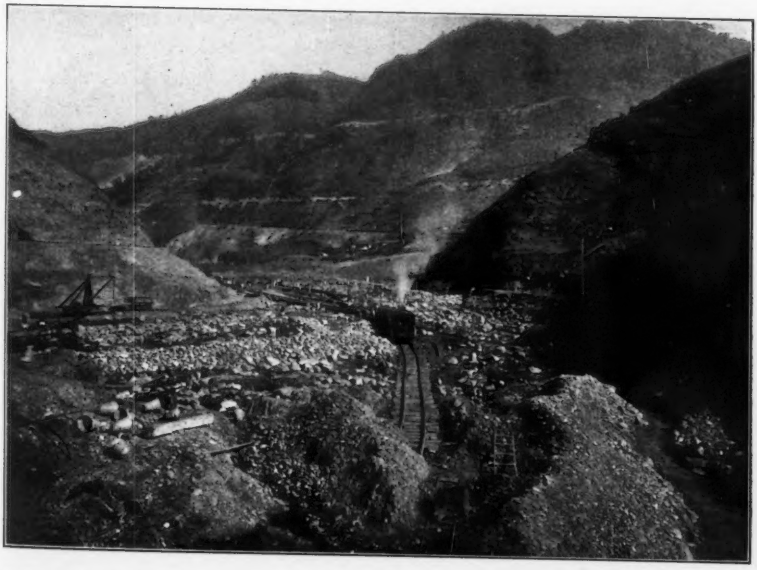


FIG. 2.—LOOKING UP STREAM AT SITE OF DAM NO. 2, AT NECAXA, SHOWING STRIPPED ABUTMENTS FOR THE DAM ON EACH SIDE.

hill it will probably be necessary to loosen the material by blasting in advance of the water jet.

For protection from muskrats and other burrowing animals, a corrugated-iron fence will be carried up from the sheet-piling to the top along the longitudinal center of the dam. This fence will not be made so tight that water may not pass through it, so that there can be no great inequality in the level of the water on either side of it in the pond on top of the dam, as the work progresses, and therefore no pressure upon the plates. These will be nailed to longitudinal girts bolted at intervals to the center line of posts in the trestle.

The water used for hydraulicing will be pumped under a pressure almost equal to a maximum head of 450 ft., including friction in the pipe and the height of the position of the monitor above the river bed, giving a pressure of about 150 lb. per sq. in. at the nozzle of the monitor. A volume of 10 cu. ft. per sec. will be used.

The minimum flow of the river is about 10 cu. m. per sec. (353 cu. ft. per sec), and will be carried through several concrete culverts.

The total volume of the dam is computed at 215 000 cu. m.

The work is in charge of Mr. M. M. Murtaugh, whose successful management of construction of the Snake River Dams, in his capacity of Assistant Manager, gave him a great familiarity with hydraulic-fill construction. The plans have been prepared by the writer, after an examination of the site.

## Failure of the Snake Ravine Hydraulic-Fill Dam, Illustrating Improper Application of the Principle.

The failure of an engineering work is often quite as instructive to the engineer as the record of successful construction, and a case of this sort may be cited in two disastrous attempts to build a hydraulic-fill dam in Snake Ravine, on the line of the Turlock Irrigation Canal, in Merced County, California, both of which failed by reason of the non-observance of correct methods. An account of this work, prepared for *Engineering News*,* by J. B. Lippincott,

* October 20th, 1899.

M. Am. Soc. C. E., details the main facts, from which the following description has been largely compiled:

The purpose of the dam across Snake Ravine was to save the construction of 1 500 ft. of side-hill canal and flume on the line of the main canal of the Turlock Irrigation District. The capacity of this canal is 1 500 cu. ft. per sec., and it was located to discharge into the basin above the dam, after passing through a divide with a cutting 50 ft. deep and 800 ft. long. The material of this cut was auriferous gravel in sizes varying from 1 in. to 2 ft., embedded in red clay, with some sand. In its original position it is extremely firm and impervious, standing for years when mined, in walls nearly vertical, as high as 50 ft. A canal used for hydraulic mining, with a capacity of 24 cu. ft. per sec. was already in existence 100 ft. above the grade of the irrigation canal and ¼ mile distant. All these conditions were simply ideal for the cheap construction of a first-class dam by the hydraulic process.

It was intended to make the dam with the material of the big cut, sluiced down by the water of the mining canal.

The dam required to be 294 ft. long on top and 64 ft. high in the center. The top width was made 12 ft., at a height of 4 ft. above the maximum water line of the canal, with slopes less than 2 to 1.

The first trial was made in 1893, but the dam went out when it had reached the 30-ft. level. The second dam was then built, and stood for some time, but went out when first tested, on June 14th, 1898. The second dam was built upon the wreck of the first, and in the same manner.

The simplest and most elementary precautions for any dam building appear to have been neglected, and no attempt was made to connect with bed-rock or remove the hydraulic mining tailings with which the ravine was filled before construction.

The plan adopted was to build up the lower toe with scraper teams, keeping it 2 ft. above the remainder of the dam. Material was then washed down with a hydraulic jet at the big cut and from the adjoining side hills of the basin, and sluiced to the dam site in the natural watercourses. An inclined shaft of wood, 2 by 4 ft. in the clear, was built inside the outer slope for carrying off waste water, and a vertical shaft of similar character was carried

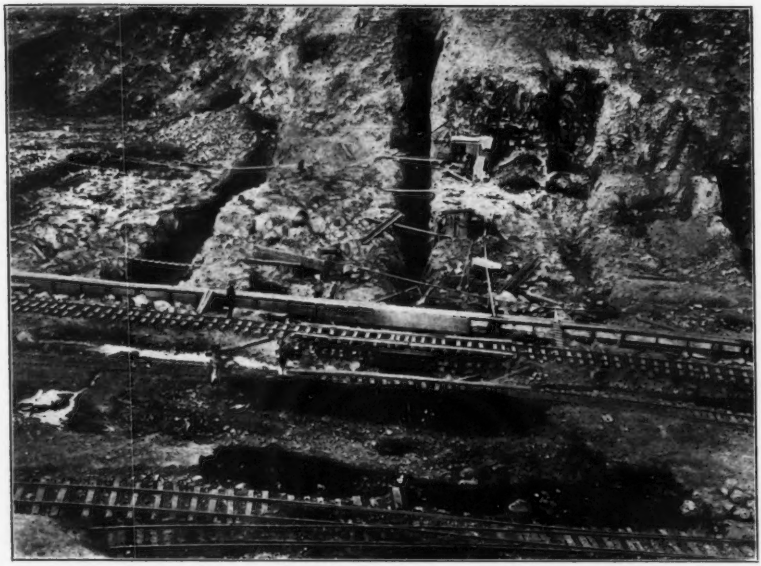


FIG. 1.—EXCAVATION FOR CUT-OFF CORE-WALL AND LATERAL TRENCHES, DAM NO. 2, NECAXA.



FIG. 2.—FOUNDATIONS AND DOUBLE EIGHT-FOOT OUTLET PIPES, FOR DAM NO. 3, AT TEZCAPA.

up at the upper toe, both connecting with a waste box of 2-in. Oregon pine, 4 ft. square, passing through the dam at the base. As no flume or pipe was used to carry the material to the outer slopes, where the gravel and boulders would be deposited, the result was that the heavier portion of the sluiced material was dropped on the way, and only the fine silt reached the dam. Without any provision for drainage, this was always in an unstable condition, constantly shaky and vibrating when jarred. It finally slid out when it had reached a height of 30 ft.

The second attempt was made with sufficiently greater care to permit of its completion to the top, but the waste box or culvert crushed in when the structure was only 40 ft. high, and could not be used thereafter. The dam was then finished to the top with carts. With water standing only a few feet deep in the basin the leakage through the dam amounted to 1 cu. ft. per sec. There was more leakage through the material deposited by carts than through the stratified material that was sluiced into position.

The intake canal passes near the east end of the dam, and a wooden box, 4 ft. square, for a new wasteway, was put in the west-end of the dam 10 ft. below the top. The intake canal is located on a steep hillside. It soon leaked and sloughed off a piece of the hillside immediately next to the dam, which then began to leak around that end. The waste box, which was also leaking, was then opened in the west cut, and washed out a large hole from the side hill and dam on its lower side. The dam was leaking at its base also. Attacked and weakened on both flank and center, the entire structure gave way and was pushed *en masse* down the ravine at a velocity of from 6 to 10 ft. per sec. It thus traveled about 1 000 ft., and was dumped into the Tuolumne River, damming the stream temporarily to a depth of 20 ft. The Superintendent and two dogs were on the dam when it gave way, and they were carried entirely across the river unhurt, although, on the trip, the man's shirt and pockets were filled with sand and mud.

After this accident the idea of building a dam was abandoned, and the ravine was crossed with a flume.

The case is cited as an example of the misuse of a most favorable opportunity for building a first-class dam with greatest

possible economy and with the best of materials, for lack of experienced and intelligent supervision. The work was done by a so-called "practical" contractor, without an engineer.

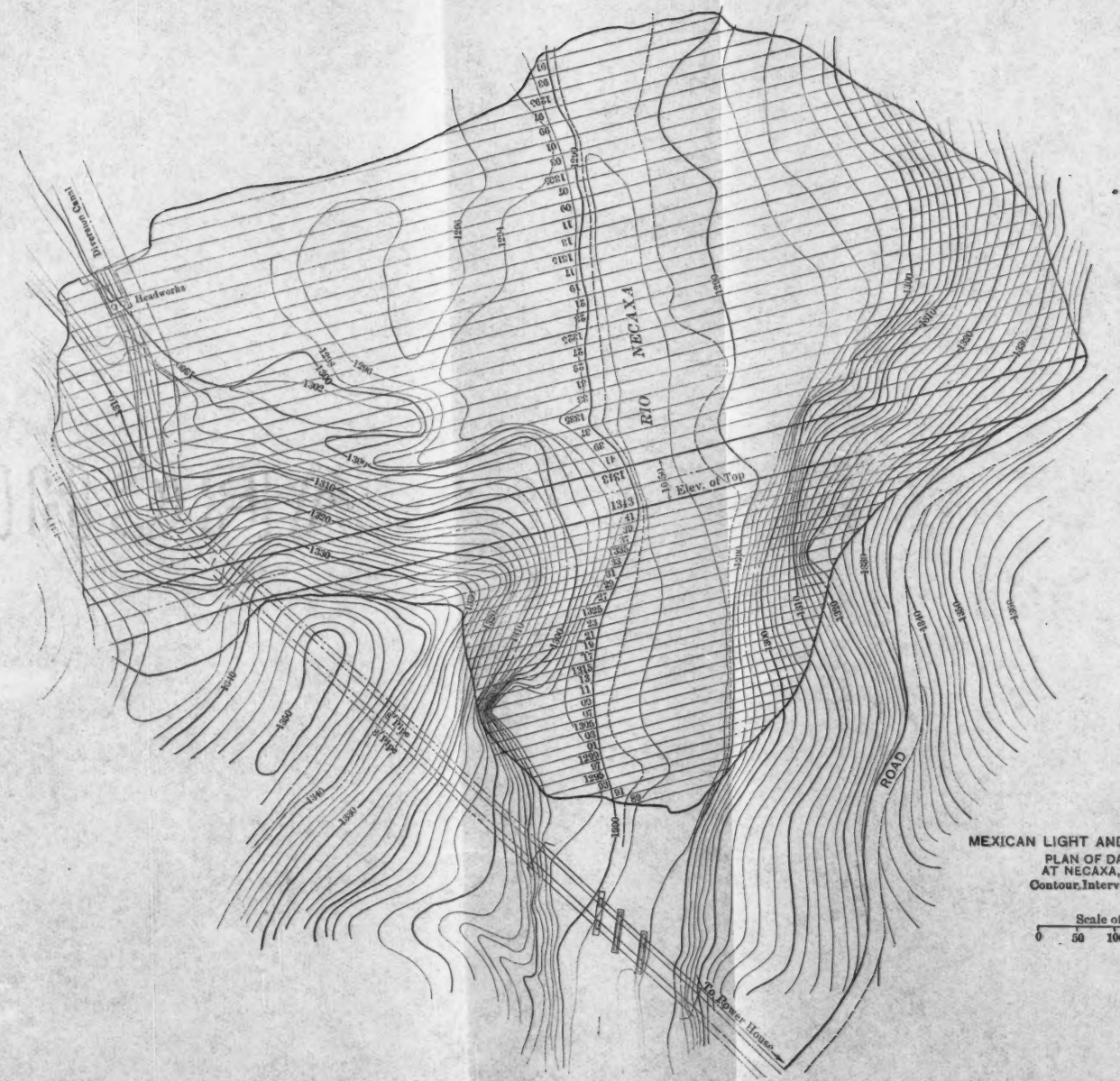
### Tyler, Texas, Hydraulic-Fill Dam.

The hydraulic-fill dam built at Tyler, Texas, for water-supply storage for that city, to which allusion was made in the early part of this paper, is 32 ft. high, 575 ft. long, and contains 24 000 cu. yd. It was built entirely with water pumped through a 6-in. pipe by a Worthington steam pump of 750 000 gal. capacity, which happened to be located exactly at the dam site. It was the original city supply pump. The entire cost of the dam was $1 140, including the spillway, outlet gate and pipe. This was an average of only 4¾ cents per cu. yd. Earth, from an adjoining hill 150 ft. high, was loosened by water forced through a 1½-in. nozzle, under a pressure of 100 lb. per sq. in., and carried down to the dam, through a pipe. The material was 65% sand and 35% clay. The dam has been in service for nearly 12 years.

### La Mesa Dam.

This hydraulic-fill structure is located near San Diego, Cal., and was built for storing waste and surplus water from the supply of the San Diego Flume Company. It is 66 ft. high, 470 ft. long, and contains 38 000 cu. yd., consisting of soil, gravel and cobble stones, loosened, transported and deposited by water. The dam was begun in February, 1895, and in the first 30 working days 55% of the work was finished. The remainder of the work took much longer, as the material became scarcer, and the distance to move it became greater, but it was completed and put in service the same year, and has been used constantly ever since. There has been a leakage of clear water coming out at the base ever since the completion of the dam, amounting to 0.2 cu. ft. per sec. when the water reaches the 54-ft. level, but it was never a source of alarm, or considered in the least menacing to the safety of the structure, and there are very good reasons for believing that it comes through the crevices of the bed-rock cliff at the north end of the dam, and not through the hydraulic-fill at all. The inner slope was covered with

PLATE XCVI.
PAPERS, AM. SOC. C. E.
OCTOBER, 1906.
SCHUYLER ON
HYDRAULIC-FILL DAMS.




MEXICAN LIGHT AND POWER CO. LTD.
PLAN OF DAM NO. 2
AT NECAXA, MEXICO.
Contour Interval, 2 Meters

Scale of Feet
0 50 100 150 200

asphalt concrete, in an attempt to stop this leakage, but without success.

Both the La Mesa and Tyler Dams were designed and built by Mr. J. M. Howells.

### The Proposed Lake Como Hydraulic-Fill Dam, in Montana.

Almost ideal conditions for the economical construction of a large dam by the hydraulic process are presented at Lake Como, in the Bitter Root Valley, Montana, where the Dinsmore Irrigation and Development Company is planning to construct a storage reservoir for irrigation supply. The dam projected will be about 2 500 ft. long on top, and have a maximum height of 93 ft. With the dimensions planned, the volume of material to be moved will be 800 000 cu. yd. The valley at the dam site, as well as the precipitous mountain slopes on either side, are composed of practically one class of material, consisting of glacial moraine gravel, boulders, sand and clay, or glacial flour. A ditch already built passes the dam at an elevation of 300 ft. above it, with ample water supply for sluicing. The dam is to be built during the current season of 1906, under the supervision of Mr. H. R. Lord, Chief Engineer, and the writer as Consulting Engineer.

Lake Como is a beautiful sheet of water, covering 196 acres, and surrounded by pine forests reaching to the water's edge. The water is clear, cold, and full of trout. The lake is said to be several hundred feet deep. The addition of 75 ft. to its depth will give the reservoir an area of 1 000 acres, and a capacity of 60 500 acre-ft.

## Conclusions.

The general principles involved in successful dam building by the hydraulic process are to be inferred from the various experiences in actual works detailed in the foregoing pages. The writer's only apology for describing these experiences with such minuteness is in order that the application of these principles, and the manifest deductions to be drawn from each distinct case, may be more clearly elucidated to those unfamiliar with this class of construction, which is not so common as to be very widely known.

In the various dams described, a great range of quality of materials has been encountered, each of which requires a special

treatment, and a great variety of conditions has been met, necessitating the exercise of ingenuity and good judgment. As far as the writer's experience has gone, it is his opinion that the best material for hydraulic-fill dams is rounded gravel, sand and boulders, intermixed with about 25 to 35% of clay. The rounded rocks roll more readily than broken angular chips, and clay acts as a lubricant to assist in transporting the heavier materials.

The most difficult material with which to build such a dam is pure clay unmixed with sand, because it is unstable until the water is drained from the mass, and drainage is very slow. The shrinkage, therefore, is much greater than in other materials, and there is greater likelihood of the opening of shrinkage cracks, months after the work is finished, through which leakage could start if the dam were put in service too soon after completion. When clay is finally consolidated, however, it makes a dam which can have no superior for water-tightness.

As a core for coarser and more stable materials, clay is extremely desirable, and its presence, with sand, gravel and rock in sufficient proportion to form one-fourth to one-third of the volume of the dam, to be segregated by water and placed in the center of the mass, makes it more easily worked, more useful, and more valuable for safe dam construction than in any greater proportions.

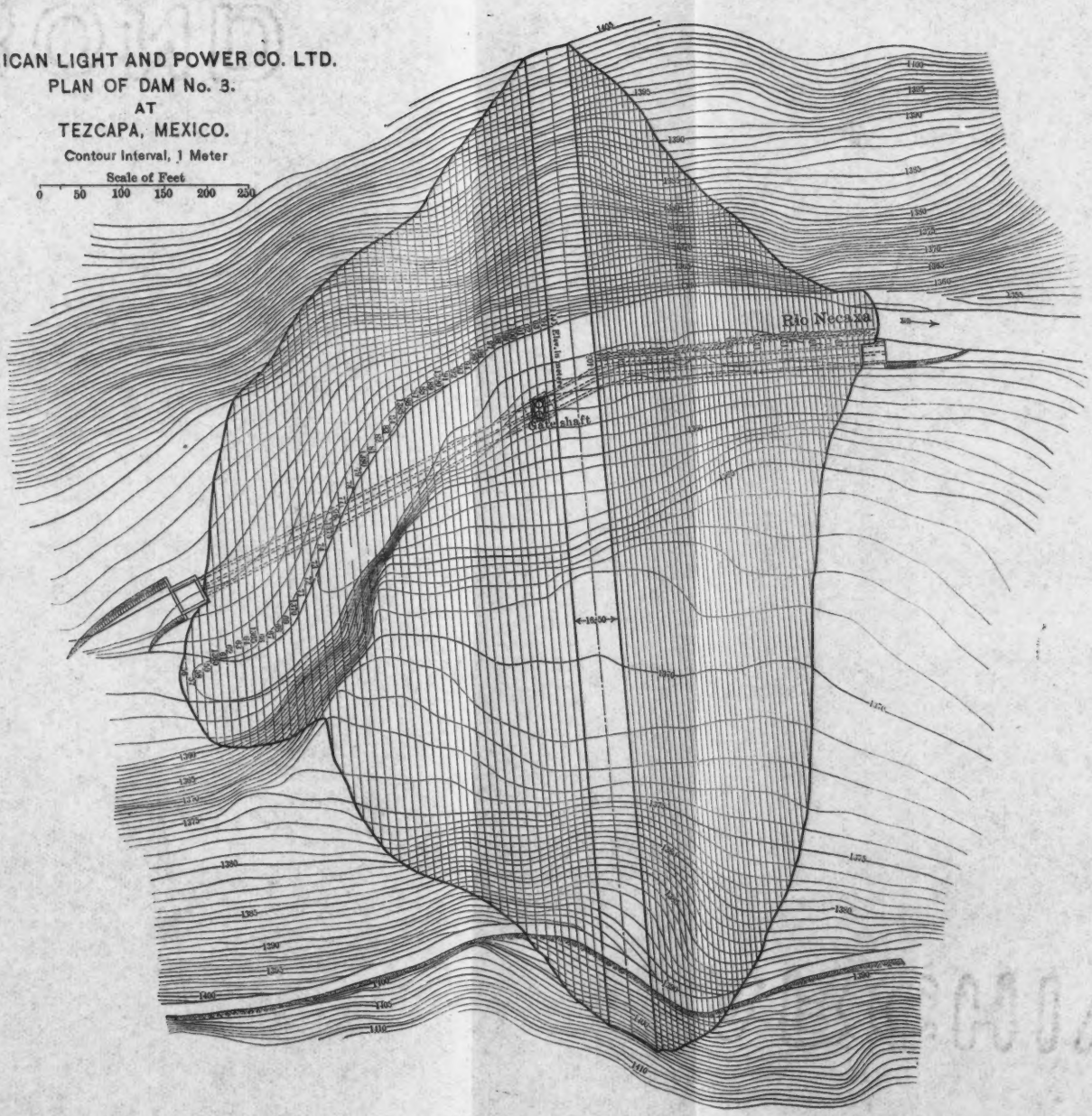
While clay is doubtless the most impervious of all earth, it is not indispensible in the building of water-tight earth dams. The volcanic ash soil of the Snake River Valley has none of the characteristics of clay, and yet it is so finely divided as to make a water-tight embankment when properly moistened and compacted. Glacial flour, which has no resemblance to clay, will also make an equally good dam.

The essential condition of any earth dam is to secure a sufficient mass of materials having particles so fine and so closely placed in juxtaposition as to oppose friction to the water seeking under pressure to penetrate between these particles to an insuperable degree. There is no limit, except one of cost, to the height which it is possible and safe to build earth dams, if they be made of sufficient dimensions to fulfil the requirement that frictional resistance to the passage of water shall be practically insuperable, or if water in moderate amount does find its way through the mass, that it shall

MEXICAN LIGHT AND POWER CO. LTD.
PLAN OF DAM No. 3.
AT
TEZCAPA, MEXICO.

Contour Interval, 1 Meter

Scale of Feet
0 50 100 150 200 250



be robbed of all velocity and power to transport any of the particles of the embankment with it, or in other words, that it shall be rendered harmless, and issue as water issues from a filter.

The hydraulic-fill process cheapens the cost of handling and compacting earth in dams so greatly as to extend widely the practicable limits of dam building, by making it feasible to increase the bulk of any dam far beyond the usual dimensions, without exceeding reasonable limits of cost. The great dams proposed in connection with the Panama Canal may possibly be much simplified in design, cheapened in cost, and increased in bulk and stability by the application of the principles herein outlined.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## THE NECAXA PLANT OF THE MEXICAN LIGHT AND POWER COMPANY.

By F. S. Pearson and F. O. Blackwell, Members, Am. Soc. C. E.

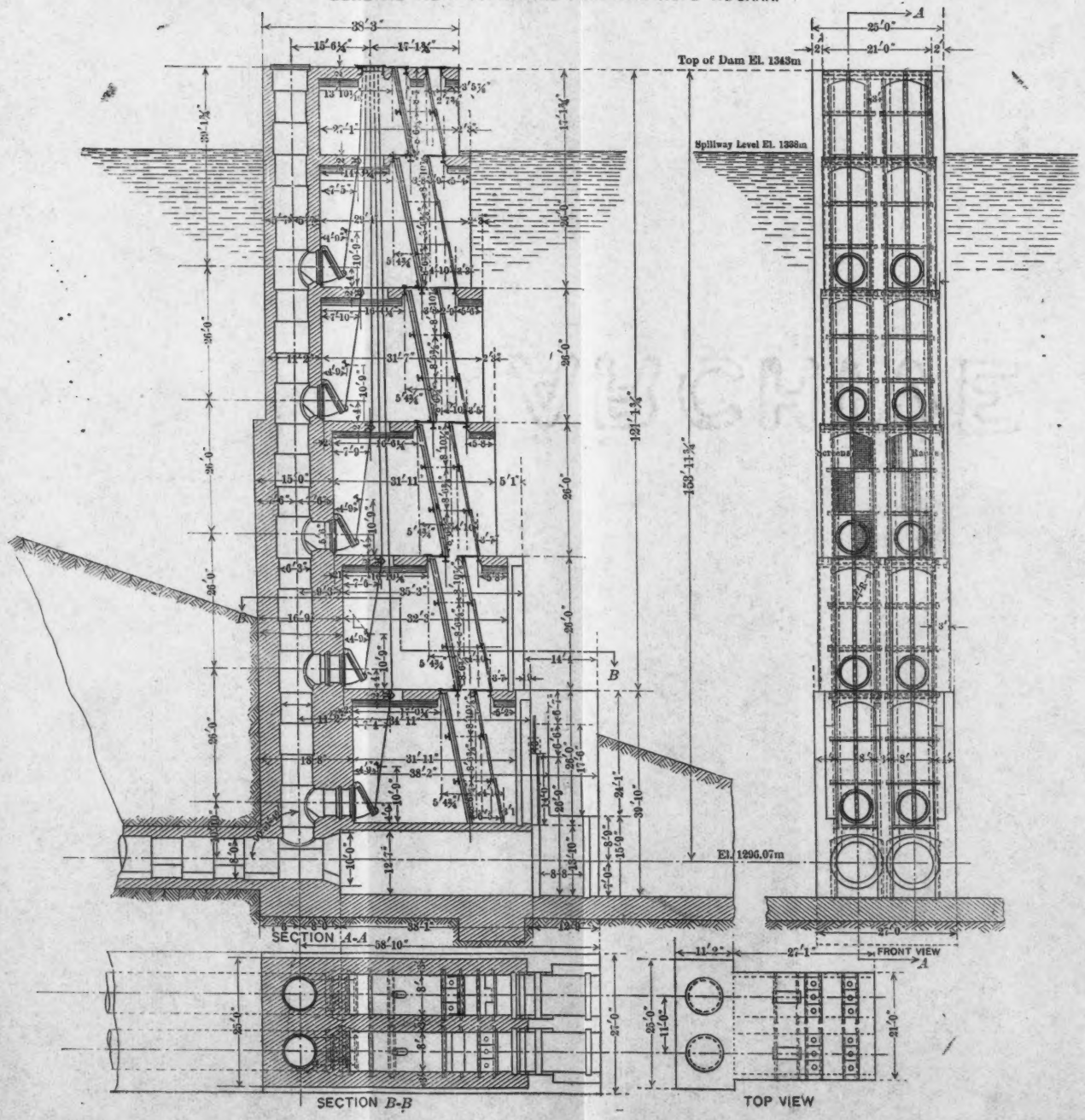
To be Presented January 2d, 1907.

The Mexican Light and Power Company was formed to develop the water power of the Necaxa, Tenango and neighboring rivers and transmit it to the Cities of Mexico and Puebla, and to the mining camps of Pachuca and El Oro. About 90 miles northeast of the City of Mexico these streams have cut through the mountains surrounding the elevated central plateau of Mexico, and fall abruptly to the low country bordering the Gulf. The rivers come together a few miles below, and eventually discharge into the Gulf of Mexico some 70 miles farther east. There is a series of picturesque falls like those in Fig. 1, Plate CV, with vertical drops of from 300 to 800 ft., and a total fall of 4 500 ft. in 10 miles.

The drainage area of the Necaxa and Tenango is approximately 200 sq. miles, which will be largely increased by diverting neighboring streams into the Necaxa Basin. There is more or less rain throughout the entire year, the heaviest precipitation occurring

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

# GENERAL VIEW OF INTAKE FOR DAM No. 2 NECAXA.



during the months of June, July, August, September and October. The driest month is May.

At Necaxa the rainfall for the 6 years during which records have been kept has varied from 85 to 135 in., with an average of 105 in., while on the upper drainage area there is only half as much precipitation. The combined flow of the two principal streams has been

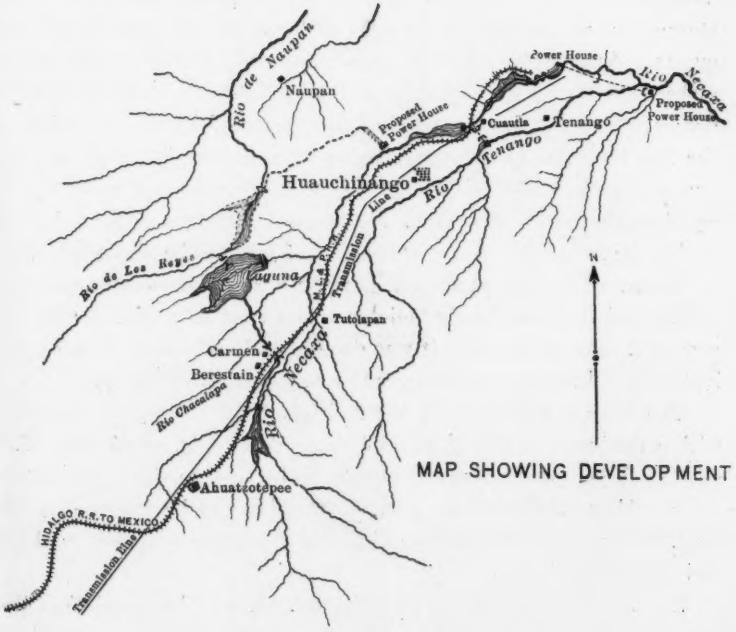



FIG. 1.

as low as 90 cu. ft. per sec., and the maximum observed flood was 3 000 cu. ft. per sec., which will probably be exceeded at times. The average run-off during the year of minimum rainfall was 245 cu. ft. per sec., and the average for 7 years was 350 cu. ft. per sec.

Fig. 1 is a map which indicates the general scheme of development. The water of the Tenango is diverted into the Necaxa Valley

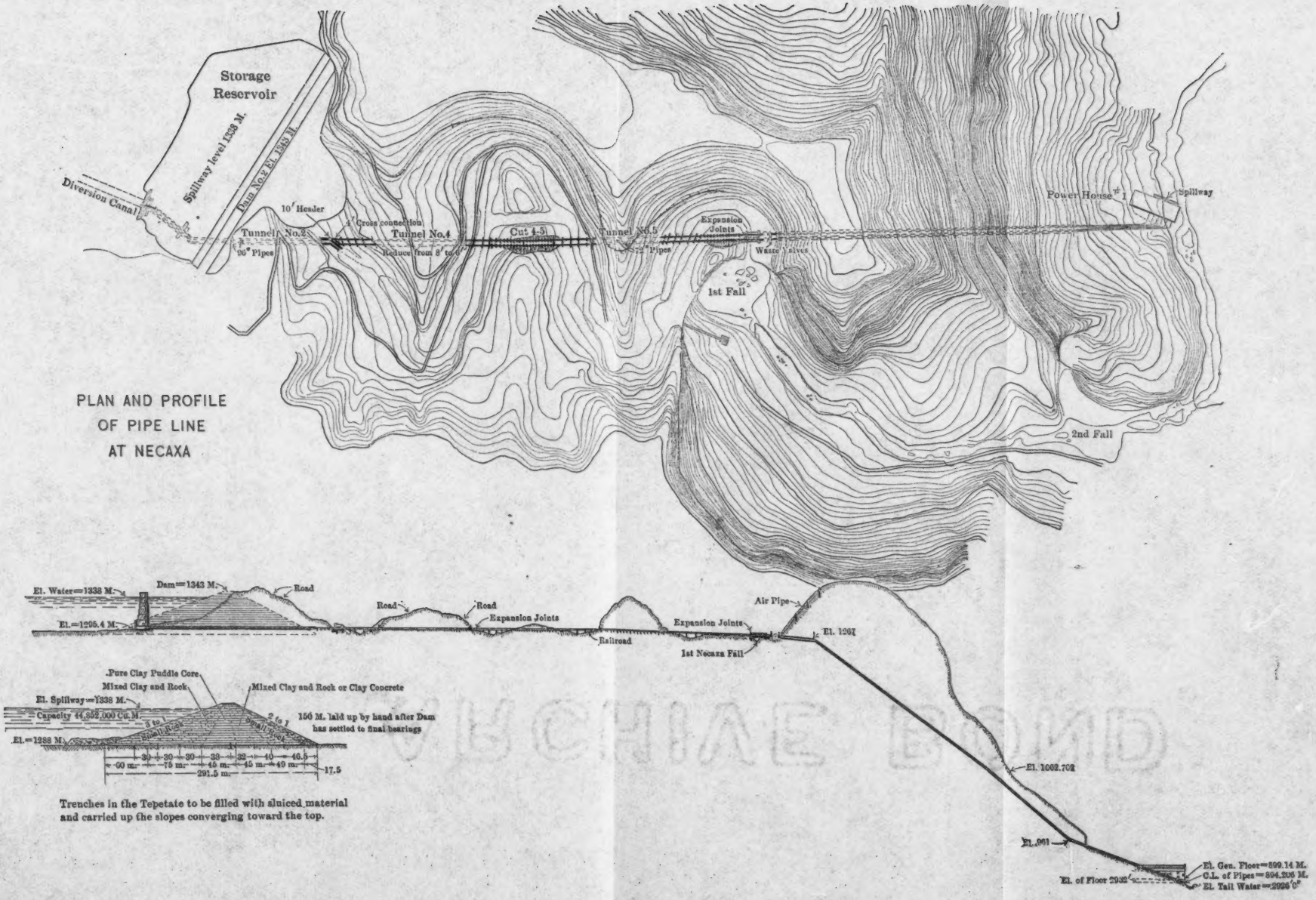
by a 40-ft. dam and a tunnel 12 ft. wide, 9 ft. high, and 3 000 ft. long. This tunnel is lined with concrete wherever there is not solid rock, and is constructed with a slope of 0.004. This will give a capacity of 875 cu. ft. per sec., which is sufficient to carry all but the extreme flood waters of the Tenango.

*Storage Reservoirs.*—No good storage basins exist on the Tenango water-shed, but there are a number on the Necaxa. Of these, the farthest down stream is the Necaxa, which is below the Tenango Tunnel, and above are the Texcapa and Laguna Reservoirs. The storage capacities will be 1 585 000 000, 642 000 000 and 700 000 000 cu. ft., respectively. The Laguna Reservoir, however, will be increased eventually to a capacity of 2 450 000 000 cu. ft. by raising the dam after its drainage area has been increased by the diversion of the Los Rayos and other neighboring streams into it. This storage, amounting to 4 600 000 000 cu. ft., will be sufficient, not only to equalize the entire run-off of the streams during any year, but to enable the average flow of a succession of years to be depended upon.

*Dams.*—The rock at the sites of the various dams is of volcanic origin and not sufficiently reliable to be used as a foundation for masonry. For this reason it was decided to build earth dams by the hydraulic-fill method, utilizing water at heads up to 400 ft.

The Necaxa Dam will be 180 ft. high, 1 276 ft. long at the crest, with a thickness of 950 ft. at the base, and of 54 ft. at the top. The slopes will be 3 to 1 on the up-stream and 2 to 1 on the down-stream faces. About 2 000 000 cu. yds. of material will be required in its construction, and this will be obtained from the neighboring hills and sluiced into place.

Fig. 2 is a cross-section of this dam. It will be noted that the faces will be covered with broken stone 8 ft. thick at the top and 60 ft. thick at the bottom. The method of construction is similar to that shown in Fig. 2, Plate CV, which is a photograph taken during the construction of the small Tenango Dam. The ground is first cleared and stripped, a trestle to support the flume is erected, and low earth dikes are made at the up-stream and down-stream limits of the fill, to hold the mud and water. The material is then sluiced in, the pipes discharging near the embankments so that the boulders and gravel are deposited on the faces, and the fine mud in the center, of the dam. The dikes are raised as the dam fills, and the water spills


Storage Reservoir
Spillway level 1338 M.
Dam No. 2 El. 1343 M.
Diversion Canal
10′ Header
Cross connection
Tunnel No. 2
Tunnel No. 4
Cut 4-5
Tunnel No. 5
Expansion Joints
Power House
Spillway
96" Pipes
Reduce from 8′ to 6′
72" Pipes
Waste Gates
1st Fall
2nd Fall
PLAN AND PROFILE
OF PIPE LINE
AT NECAXA
El. Water = 1338 M.
Dam = 1343 M.
Road
El. = 1295.4 M.
Expansion Joints
Railroad
Air Pipe
El. 1297
1st Necaxa Fall
Pure Clay Puddle Core
Mixed Clay and Rock
Mixed Clay and Rock or Clay Concrete
El. Spillway = 1338 M.
Capacity 44,852,000 Cu. M.
150 M. laid up by hand after Dam has settled to final bearings
El. = 1288 M.
Small Rock
30 30 30 33 32 40 46.5
60 m. 75 m. 45 m. 45 m. 49 m.
291.5 m.
17.5
Trenches in the Tepetate to be filled with sluiced material
and carried up the slopes converging toward the top.
El. 1062.702
El. 991
El. Gen. Floor = 899.14 M.
C.L. of Pipes = 894.206 M.
El. Tail Water = 2926′ 0″
El. of Floor 2932′

over the up-stream face into the pond. During construction the water of the river is passed through the discharge gates, which are made large enough for the purpose. A spillway is provided for the Necaxa Reservoir over a neck of rock to the north of the dam, and the overflow returns to the river below the power-house. The outlet is through a rock tunnel, 1 550 ft. long, near the southern end of the dam and 153 ft. below the crest. The water is admitted to the pipe lines through the gates shown in Plate XCVIII. In order to avoid the operation of gates and racks under such high pressures, two vertical stand-pipes, each with five flood-gates, have been constructed, either of which will permit all the water required for power purposes to pass. By this arrangement it will not be necessary to operate the gates or racks under a head of more than 26 ft.

The Texcapa Dam will have a height of 174 ft., a thickness of 905 ft. at the base, and a length of 1 191 ft. at the crest.

The small Laguna Dam now being constructed will have a height of 40 ft., a length of 400 ft., and will form the up-stream toe of the higher dam.

*Pipe Lines.*—Two riveted steel

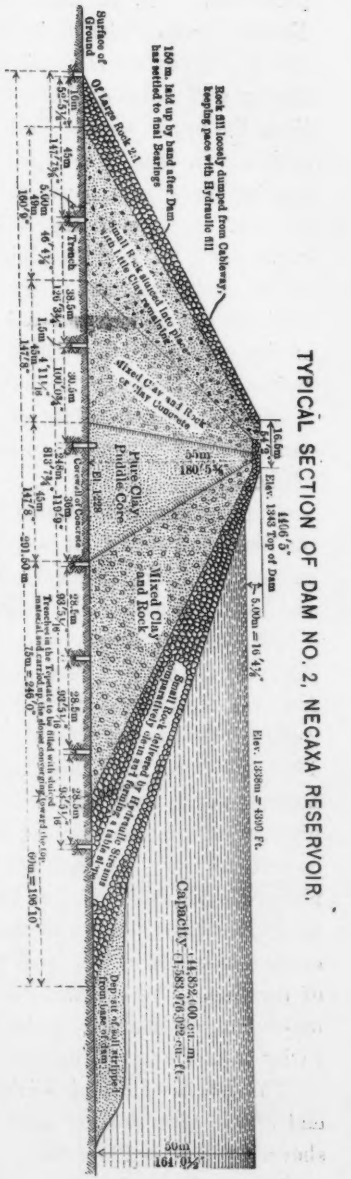



Fig. 2.

penstocks, 8 ft. in diameter and $\frac{5}{8}$ in. thick, pass through the Necaxa Tunnel, with sluice-gates discharging into the river. Below this point they are reduced to a diameter of 6 ft. and continue down stream a distance of 2 200 ft., 800 ft. of which is through tunnels. Near the upper Necaxa Fall these pipes are joined by two receivers, each 22 ft. long and 7 ft. in diameter. From the receivers six smaller pipes pass down to the power-house through two incline tunnels. On each of the 30-in. pipes there are relief valves, 30 in. in diameter, pipes from which lead up the hillside 310 ft. to an elevation above the crest of the dam. All pipes are connected with the receivers through valves, and a central gate separates the two halves of the system, so that either half can be shut down without interfering with the other, as shown in Fig. 1, Plate CVI.

Two expansion joints of the diaphragm type are provided in each of the 6-ft. pipe lines, and there are packed slip-joints in each of the 30-in. pipes.

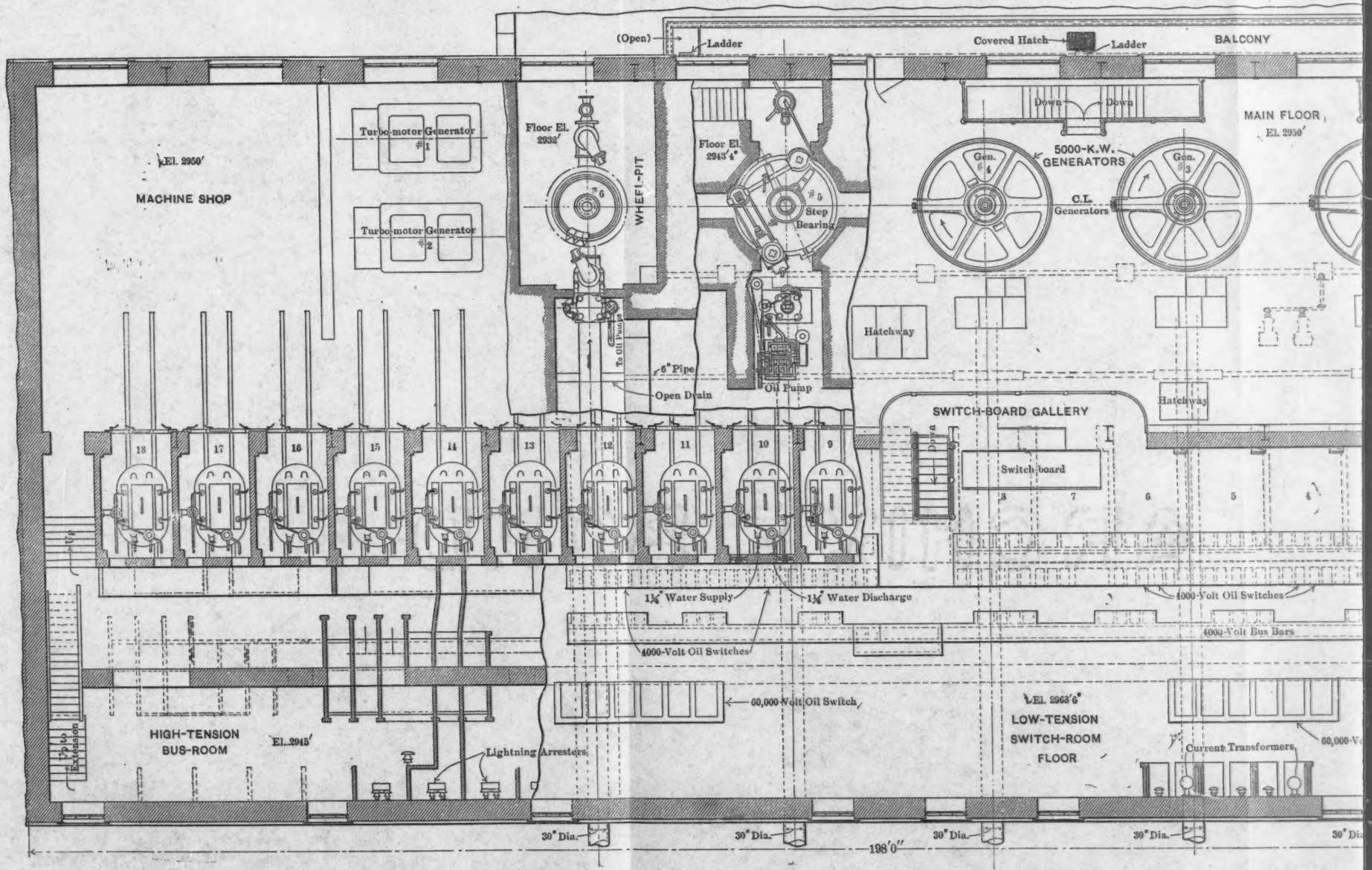
The velocity of the water in the upper and lower pipe lines, when the plant is running at full load, is 7.5 and 15 ft. per sec. Under extreme overload conditions, the velocity is at times as high as 8.7 and 18 ft. per sec.

All pipes are supported on concrete piers throughout their length. Plate XCIX shows a plan and profile of the pipe line. The six pipes from the receiver are carried down to the power-house, a distance of 2 460 ft., the upper 1 900 ft. of which is through two parallel tunnels, 13 ft. wide and 10 ft. high, constructed at an angle of 41° from the horizontal. A track and cableway will be constructed on top of the pipes in one tunnel, through which supplies for the power-house will be transported. The pipes with flanges are forged complete from one piece of sheet steel. Before the flanges are hammered out, two cast-steel clamping rings are slipped on each 30-ft. section of pipe. The outside diameter of the tubes is $30\frac{5}{8}$ in. throughout the entire length of the line. The internal diameter is less at the lower than at the upper end, on account of the greater thickness of the metal, which varies from 0.4 to 0.95 in., the minimum diameter being 29 in.

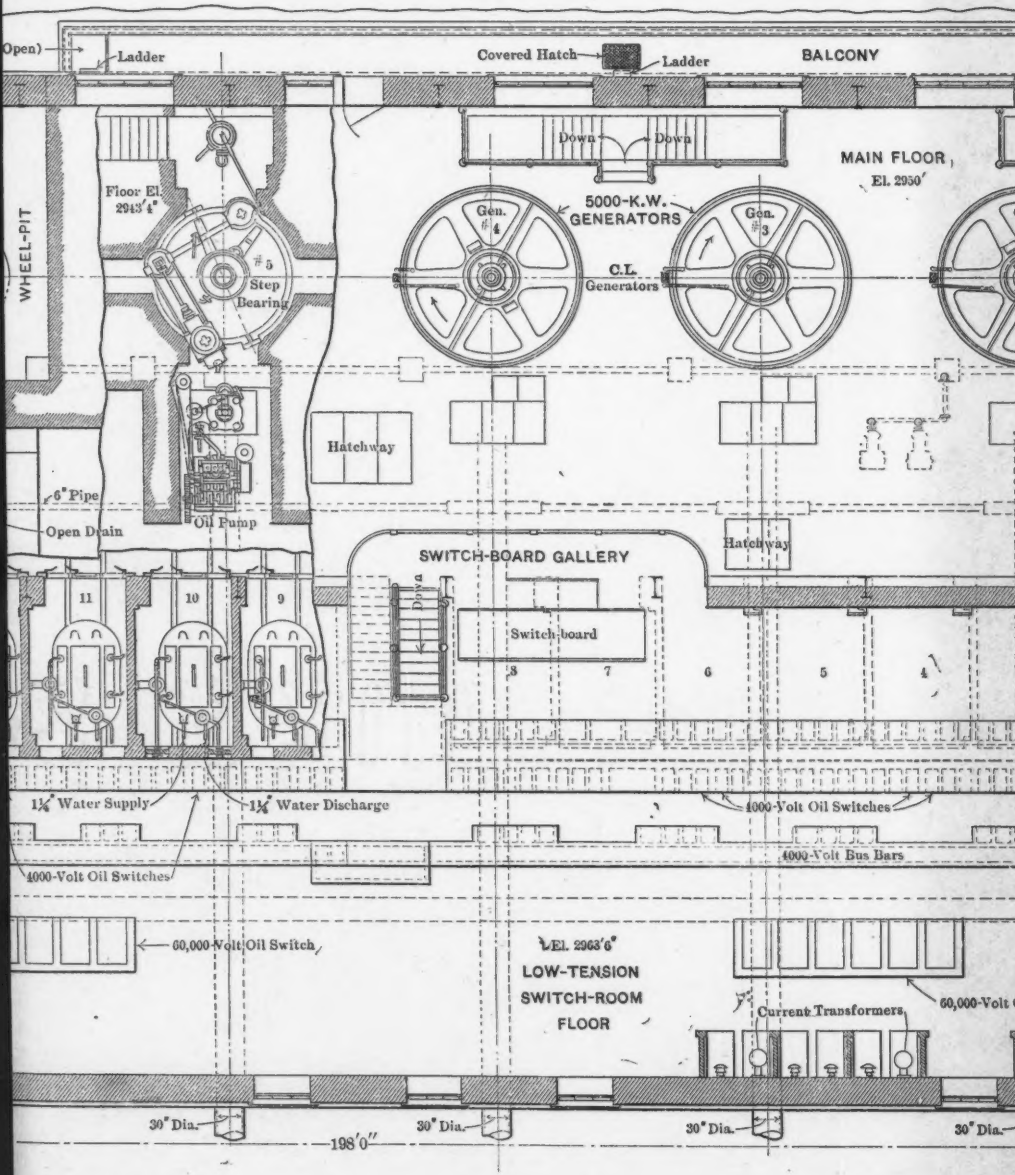
The details of the pipe joints are shown in Fig. 3, and the lower end of the pipe line, as seen from the roof of the power-house, is shown by Fig. 2, Plate CVI.

The static head at the water-wheel, with the reservoir full, is

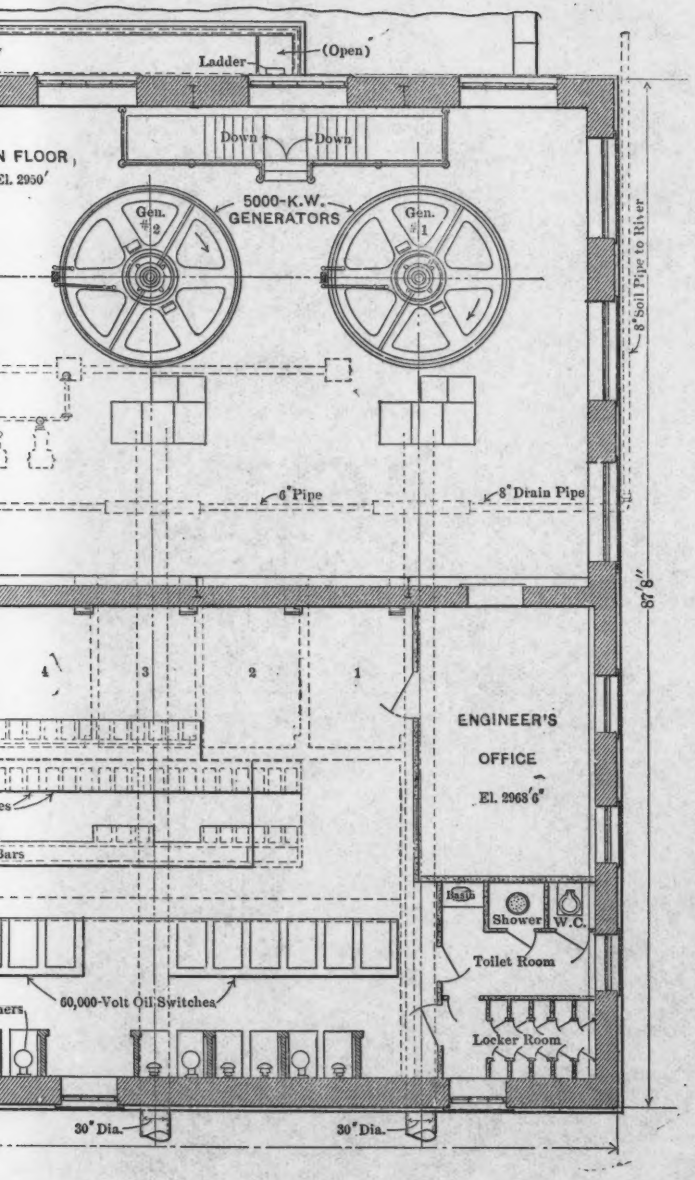
# GENERAL PLAN OF POWER-HOUSE NO.1. SHOWING DIFFERENT FLOOR LEVELS. NECAXA.



OF POWER-HOUSE NO.1. SHOWING DIFFERENT FLOOR LEVELS. NECAXA.



KA.


Ladder
(Open)
Down
Down
N FLOOR,
El. 2950′
Gen. #2
5000-K.W. GENERATORS
Gen. #1
8″ Soil Pipe to River
6″ Pipe
8″ Drain Pipe
87′6″
4
3
2
1
ENGINEER'S OFFICE
El. 2963′6″
es
Bars
Basin
Shower
W.C.
Toilet Room
60,000-Volt Oil Switches
ers
Locker Room
30″ Dia.
30″ Dia.

1 452 ft., which in service is reduced to between 1 200 and 1 300 ft. by the reservoir surface being lowered and by frictional and other losses.

Each section of tube, before being shipped from the works of the manufacturer, The Actien Gesellschaft Ferrum, of Kottowitz, Germany, was subjected to a hydrostatic test of one and three-quarters

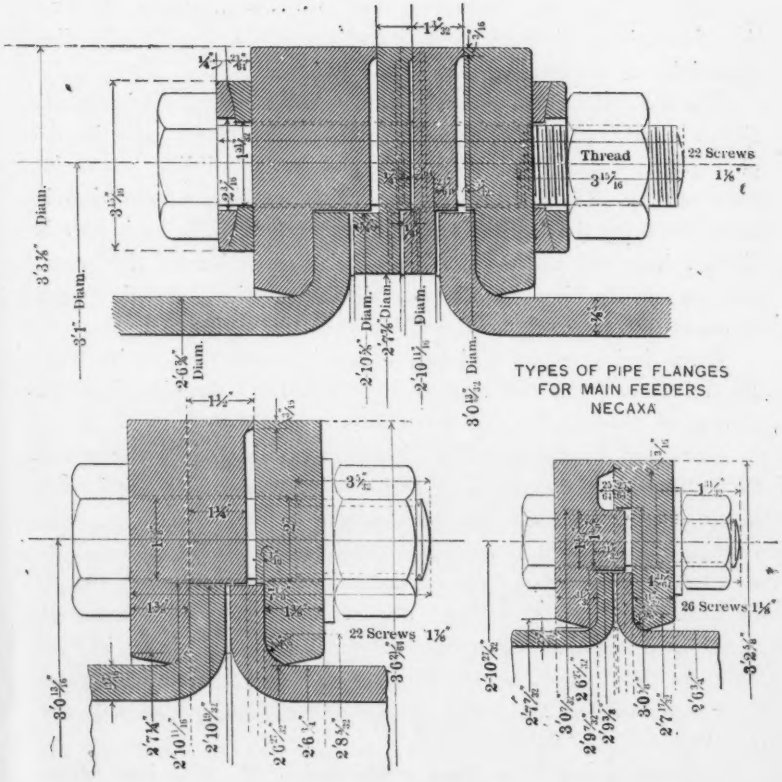



FIG. 3.

times the maximum pressure which it is under in service. The form of pipe is stronger and more reliable than one built up of plates riveted together, and the smooth interior will materially reduce the loss of head due to friction, especially at the higher velocities occurring at times of overload.

*Power-House.*—The power-house is located in the cañon below the lower Necaxa waterfall, with a vertical drop of 740 ft., as illustrated in Fig. 1, Plate CVII.

The building stands on a massive concrete base which forms the foundation for the hydraulic and electric machinery. The walls are of concrete, with steel columns in the front and center to support the crane girders and roof trusses.

The roof is of ferro-inclave covered with cement plaster, the window frames are of steel, the floors of cement, and no combustible materials are used in any part of the structure.

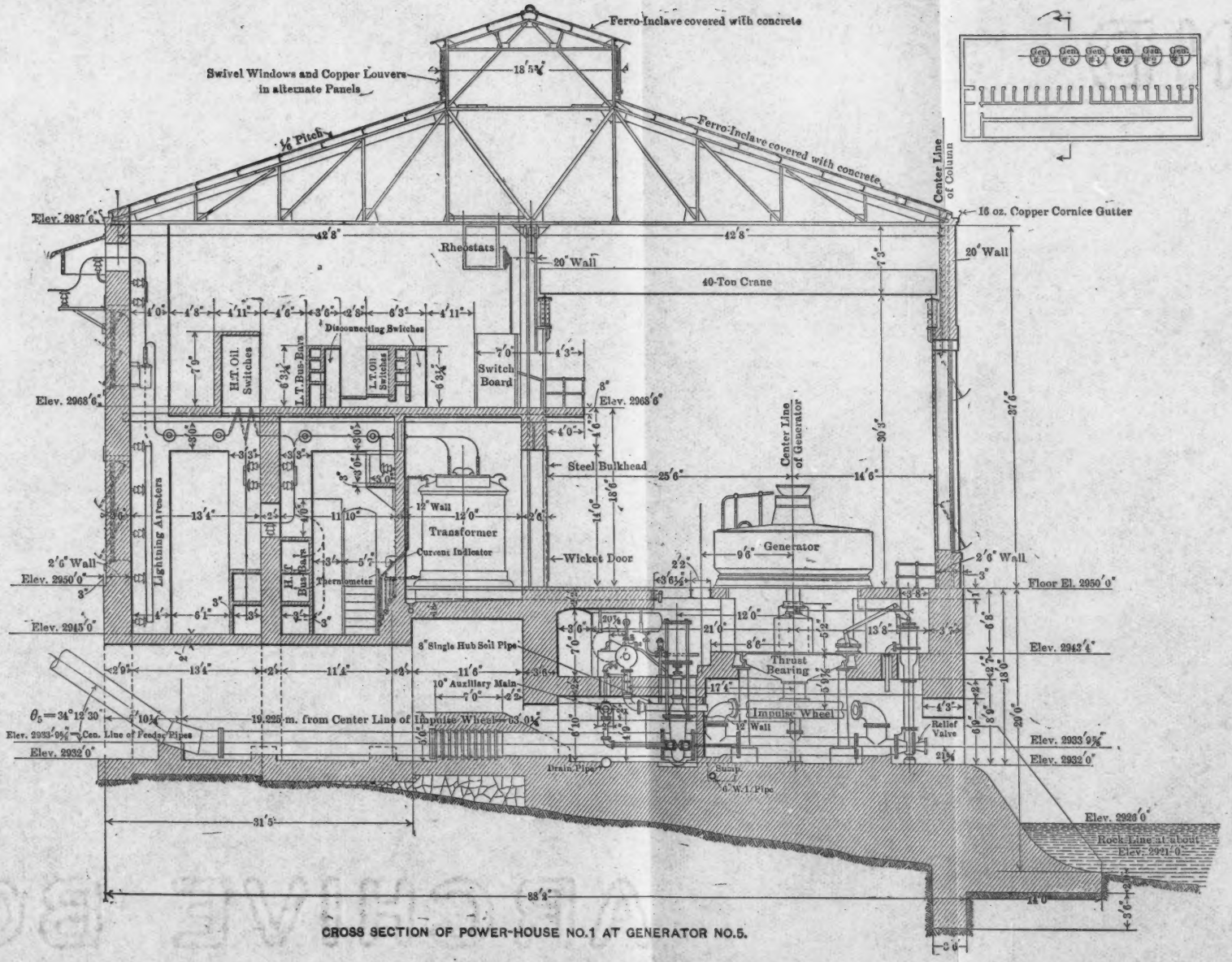
The dimensions and general arrangement of the power-house are shown on the plan and elevation, Plates C and CI, and in the photograph, Fig. 2, Plate CVII, taken while the building was under construction. The front half, over which travels a 40-ton electric crane, contains the water-wheels and generators. The back part is divided into two stories, the lower being occupied by the transformers and the high-potential electrical connections, and the upper by the switches, switch-board and low-potential wiring.

The building is 235 ft. long, 88 ft. wide, and 37 ft. 6 in. from the main floor to the roof trusses. At one end is a machine shop and store-room for supplies and spare parts.

*Hydraulic Apparatus.*—The pipe lines pass into the basement of the building and terminate in 28-in. valves operated by hydraulic power. Each of the six impulse-wheels is rated at 7 000 h. p., with a maximum capacity of 9 000 h. p., making it possible to supply a peak load of 50 000 h. p. from the station. The wheels are of 100 in. pitch diameter, run at 300 rev. per min., and have solid cast-steel center discs to which are clamped 24 steel buckets, as shown in Fig. 1, Plate CVIII. Each has two 4½-in. square, regulating nozzles fixed on opposite sides of the wheel, but joined together, so that they are opened and closed simultaneously.

A by-pass valve is provided at the end of the pipe line which feeds each unit, and is mechanically connected to the nozzles, so that when one opens the other closes, keeping the flow of water in the pipe constant. This entirely avoids the possibility of rams, which might prove disastrous with such a long penstock and high velocity.

A vertical shaft, 14 in. in diameter, and flanged at the bottom to take the water-wheel disc, carries the revolving parts of both the




CROSS SECTION OF POWER-HOUSE NO.1 AT GENERATOR NO.5.

generator and water-wheel. The weight is supported by a thrust-bearing, 30 in. in diameter, under which oil is forced, at a pressure of 150 lbs. per sq. in., by a pump driven either by a small water-wheel or by a belt from each main wheel. This construction has many marked advantages for large units over impulse water-wheels heretofore built with horizontal shafts and single deflecting nozzles. The double nozzle reduces the size of both the jet and the bucket, and permits the use of a water-wheel of smaller diameter and higher speed of rotation without sacrifice of efficiency. The mechanism is more easily operated than a deflecting nozzle, and the two nozzles being set in opposition to each other there is no thrust on the steady bearings, and all the parts can be made much smaller than would have been required for a horizontal shaft. The diameter and length of the shaft itself can also be much reduced. The oil thrust-bearing is a very simple and reliable device which operates with a minimum of attention. The maximum quantity of water supplied to each wheel can be adjusted at the governor, so that water will not be wasted unnecessarily, and the by-pass is also arranged so that it can be adjusted to close slowly after opening—a feature which is desirable with fairly steady loads.

The governor controls the valves which admit either oil from the pump (which supplies the thrust-bearing), or water from the penstock, to the pistons which operate the nozzles and by-pass. Under actual running conditions the speed regulation is extremely close, and the by-pass wastes practically no water except when the circuit breakers throw the full load off the plant instantly.

All the hydraulic apparatus was supplied by Escher-Wyss and Company, of Zurich, Switzerland.

*Electric Apparatus.*—Each water-wheel drives a 5 000-kw. alternator, of the revolving-field type, which generates three-phase current at a periodicity of 50 cycles, and a potential of 4 000 volts. Two of the alternators are equipped with a 60-kw. direct-connected, 125-volt exciter, but in ordinary operation exciting current will be obtained from two 250-kw., 125-volt generators driven by induction motors wound for 4 000 volts. Exciting sets taking power from the main units are used because with small wheels the nozzles are constantly getting stopped up by materials floating in the water. The generator is shown by Fig. 2, Plate CVIII.

The low-potential current from the generators is raised to a pressure suitable for long-distance transmission by five banks of oil transformers, each bank consisting of three 2 000-kw. units, which can deliver power, at 40 000, 50 000, or 60 000 volts, to the transmission circuits. The transformers are shown in Fig. 1, Plate CIX. They are placed in a closed fire-proof compartment separated from the generator-room by steel bulkheads on account of the large quantity of oil used for insulation. The heat generated in the transformers, due to the losses in the iron and copper, is carried away by copper cooling coils in the cases, through which water is constantly circulated by motor-driven pumps. Plate CII is a diagram of the electrical connections, which are made as simple and direct as possible.

The wiring consists either of insulated cables in conduits or of bare wires in brick and concrete compartments, so that the damage from an arc is limited, and cannot injure adjoining circuits. This is particularly important in laying out the 60 000-volt conductors, and a substantial concrete wall isolates every wire, switch or lightning arrester. The main switches are all of the oil type, controlled electrically from a distance, and any switch will open instantaneously a short-circuit of the entire power system. They are also equipped with disconnecting air switches so that the oil switches and other devices can be cut off from the system for repair and inspection.

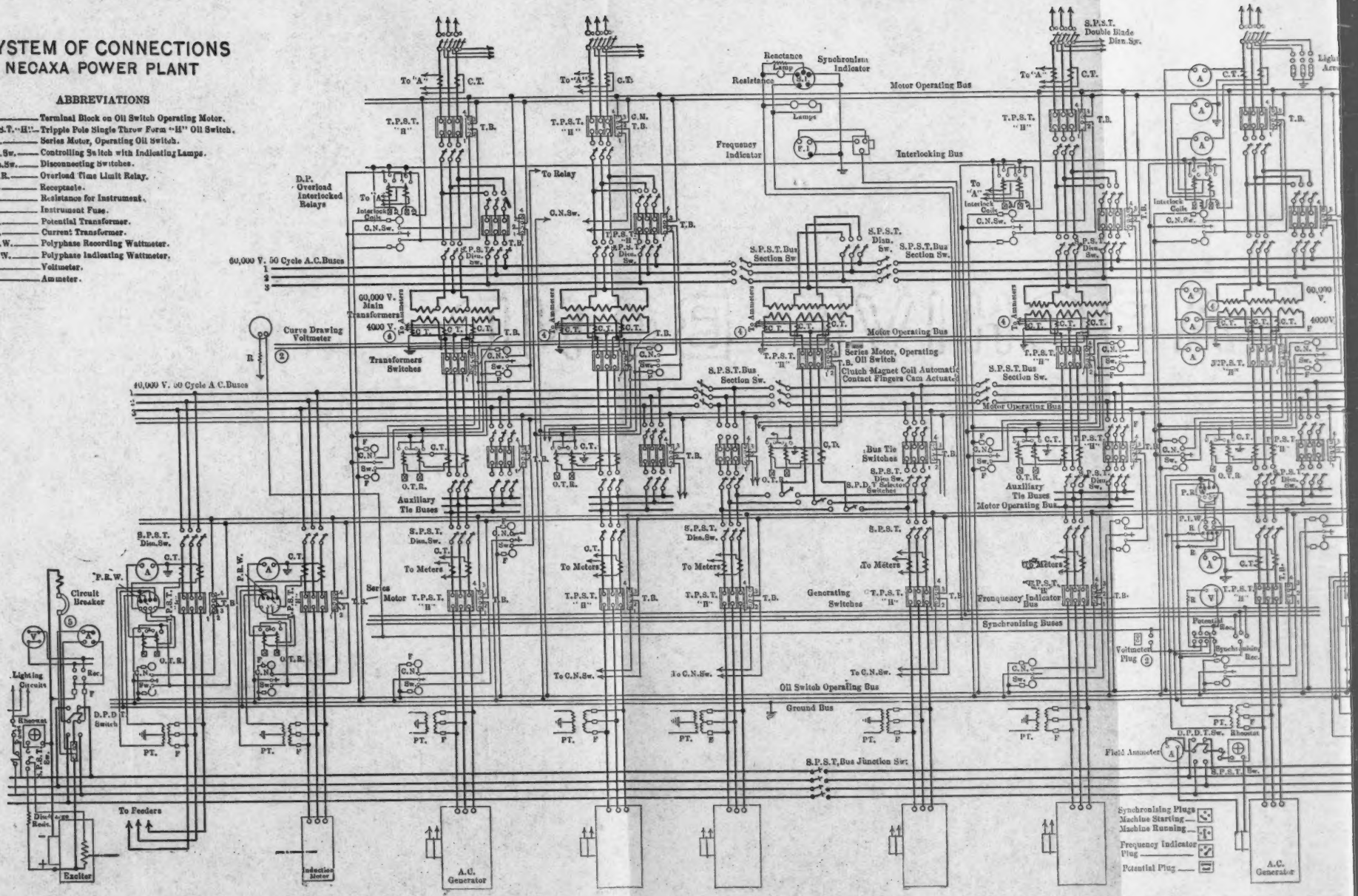
The oil switches are on the gallery, with the controlling switch-board in the center, where the operator can obtain an unobstructed view of the machinery in all parts of the building. The small controlling switches for the large oil switches, with the miniature lamps which indicate their position, are mounted on a bench-board with dummy bus-bars to form a wiring diagram, so that the attendant can always see how the apparatus is connected, and thus avoid mistakes.

On vertical panels above the bench-board are the indicating instruments which show at any instant the speed, potential and power at which the plant is operating. These instruments are also placed in such a manner, with relation to the dummy busses and operating switches, that the operator cannot become confused. At the back of the board are the registering instruments which make a record of the pressure and output of the plant. The switch-board forms a

# SYSTEM OF CONNECTIONS
## NECAXA POWER PLANT

### ABBREVIATIONS

T.B.——Terminal Block on Oil Switch Operating Motor.
T.P.S.T. "H"—Tripple Pole Single Throw Form "H" Oil Switch.
S.M.——Series Motor, Operating Oil Switch.
C.N.Sw.——Controlling Switch with Indicating Lamps.
Disn.Sw.——Disconnecting Switches.
O.T.R.——Overload Time Limit Relay.
Rec.——Receptacle.
R.——Resistance for Instrument.
F.——Instrument Fuse.
P.T.——Potential Transformer.
C.T.——Current Transformer.
P.R.W.——Polyphase Recording Wattmeter.
P.I.W.——Polyphase Indicating Wattmeter.
V.——Voltmeter.
A.——Ammeter.



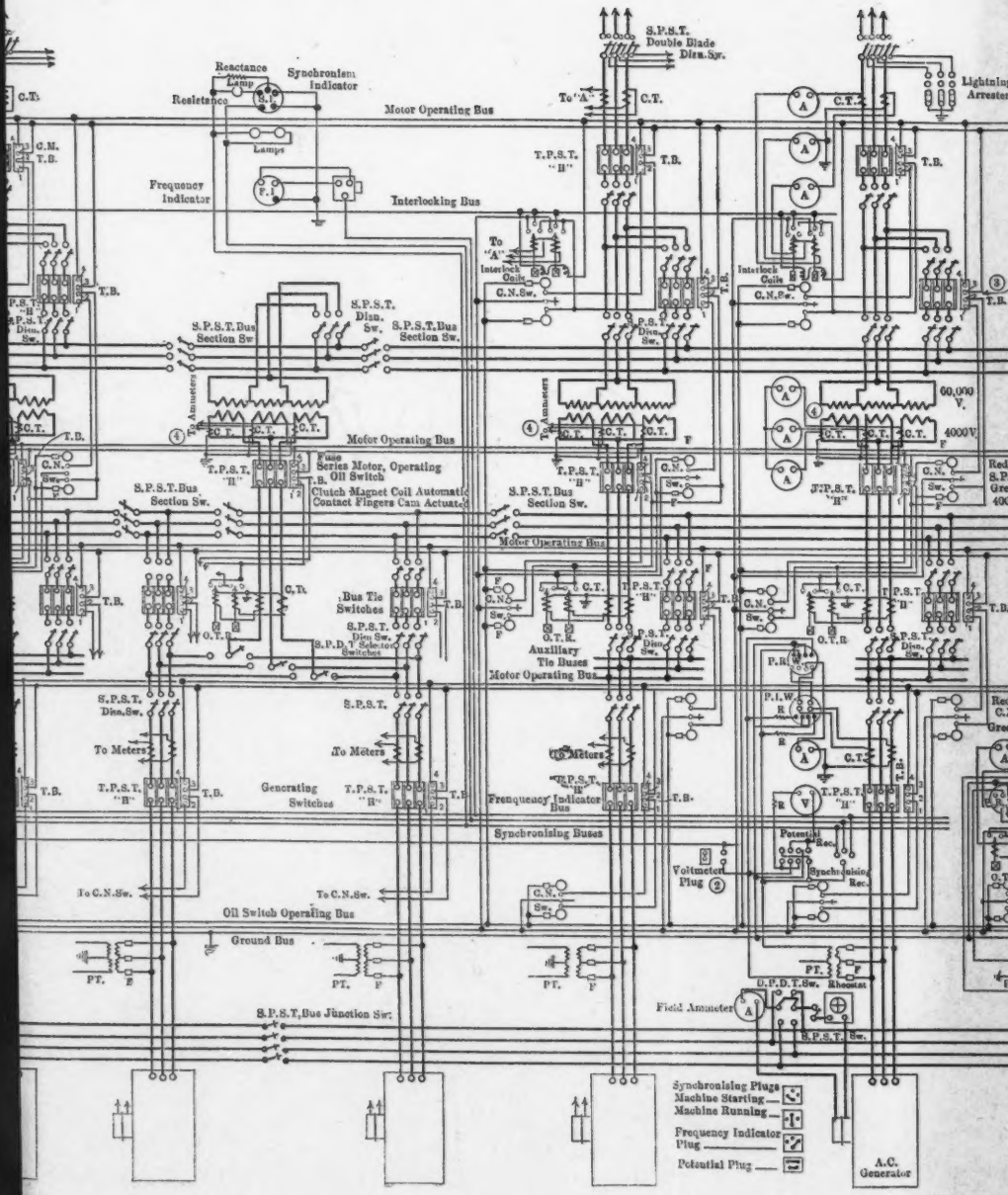
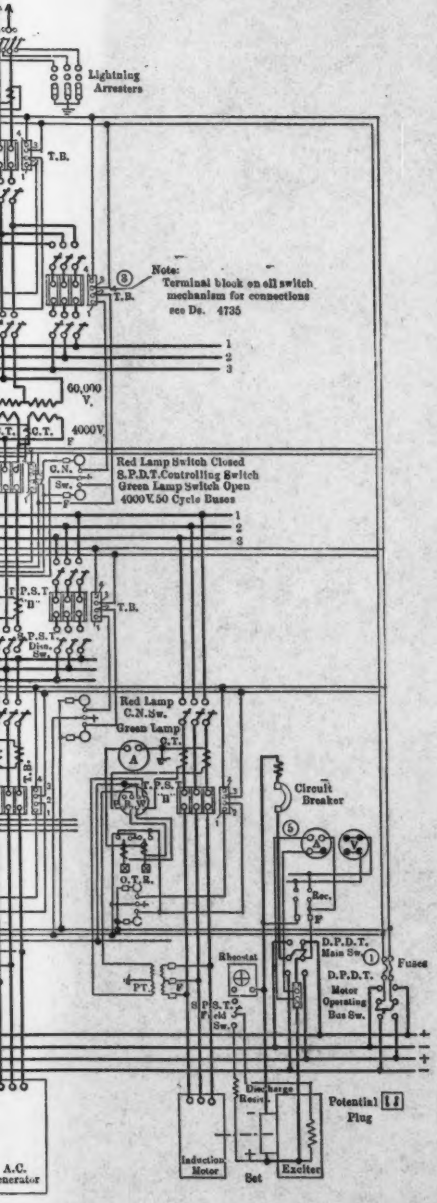

S.P.S.T. Double Blade Disn.Sw.
Reactance
Lamp
Synchronism Indicator
Resistance
Motor Operating Bus
To "A"
C.T.
Lightning Arrester
Lamps
T.P.S.T. "H"
T.B.
Frequency Indicator
Interlocking Bus
Interlock Coils
C.N.Sw.
S.P.S.T. Disn. Sw.
S.P.S.T.Bus Section Sw.
P.S. Disn. Sw.
60,000 V.
4000V
Fuse
Series Motor, Operating Oil Switch
Clutch Magnet Coil Automatic Contact Fingers Cam Actuated
Bus Tie Switches
S.P.D.T. Selector Switches
O.T.R.
Auxiliary Tie Buses Motor Operating Bus
P.R.
P.I.W.
To Meters
Generating Switches
Frequency Indicator Bus
Synchronising Buses
Voltmeter Plug
Potential Rec.
Synchronising Rec.
To C.N.Sw.
Oil Switch Operating Bus
Ground Bus
PT.
S.P.S.T.Bus Junction Sw.
D.P.D.T.Sw. Rheostat
Field Ammeter
S.P.S.T. Sw.
Synchronising Plugs
Machine Starting
Machine Running
Frequency Indicator Plug
Potential Plug
A.C. Generator

PLATE CII.
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PEARSON AND BLACKWELL ON
LIGHT AND POWER PLANT.



room surrounded by ornamental ironwork, with the instruments and controlling devices on the outside, and doors at the ends to give access to the inside connections, as shown in Fig. 2, Plate CIX. The transformers and switch-board were furnished by the General Electric Company, of Schenectady, N. Y. The generators and exciters were supplied by the Siemens-Schuckert-Werke, of Berlin.

*Construction Plant.*—The Necaxa development being located in one of the most inaccessible parts of the State of Puebla, it was first necessary to establish communications, by constructing some 30 miles of wagon roads. At the start, traction engines were used, but proved unsatisfactory, on account of the constant rains during the first year of active operation, and eventually the Hidalgo Railroad was extended to Beristain, from which point the Mexican Light and Power Company built its own narrow-gauge line 21 miles to Necaxa. This road is remarkable from the fact that only 10% of it is tangent, many of the curves are of 60 ft. radius, and the grade for a considerable portion of the line is 6 per cent.

The company now operates some 27 miles of track, 3 Shay locomotives and 20 flat cars, in addition to the locomotives and cars used in excavation work.

The machinery and materials for the power-house were lowered at the two falls by cableways capable of handling 15 tons.

A temporary plant of 1 000 h. p. at the upper falls supplied 500-volt continuous current for lighting and power, and compressed air for construction purposes.

An engineering camp for the management was built on the mesa, 1 700 ft. above the power-house, and three new towns, to house the 4 000 Mexicans employed on the work, and to replace the native villages flooded out by the reservoirs, were built.

*Extensions of Power Plant.*—The future plans of the Mexican Light and Power Company contemplate the construction of another power-house, immediately below the existing one, to utilize the same water under a head of 700 ft. and developing 20 000 h. p. There is also a fall of 2 100 ft. between the Laguna and Texcapa Dams, which will be developed when required, and can furnish 30 000 h. p. additional.

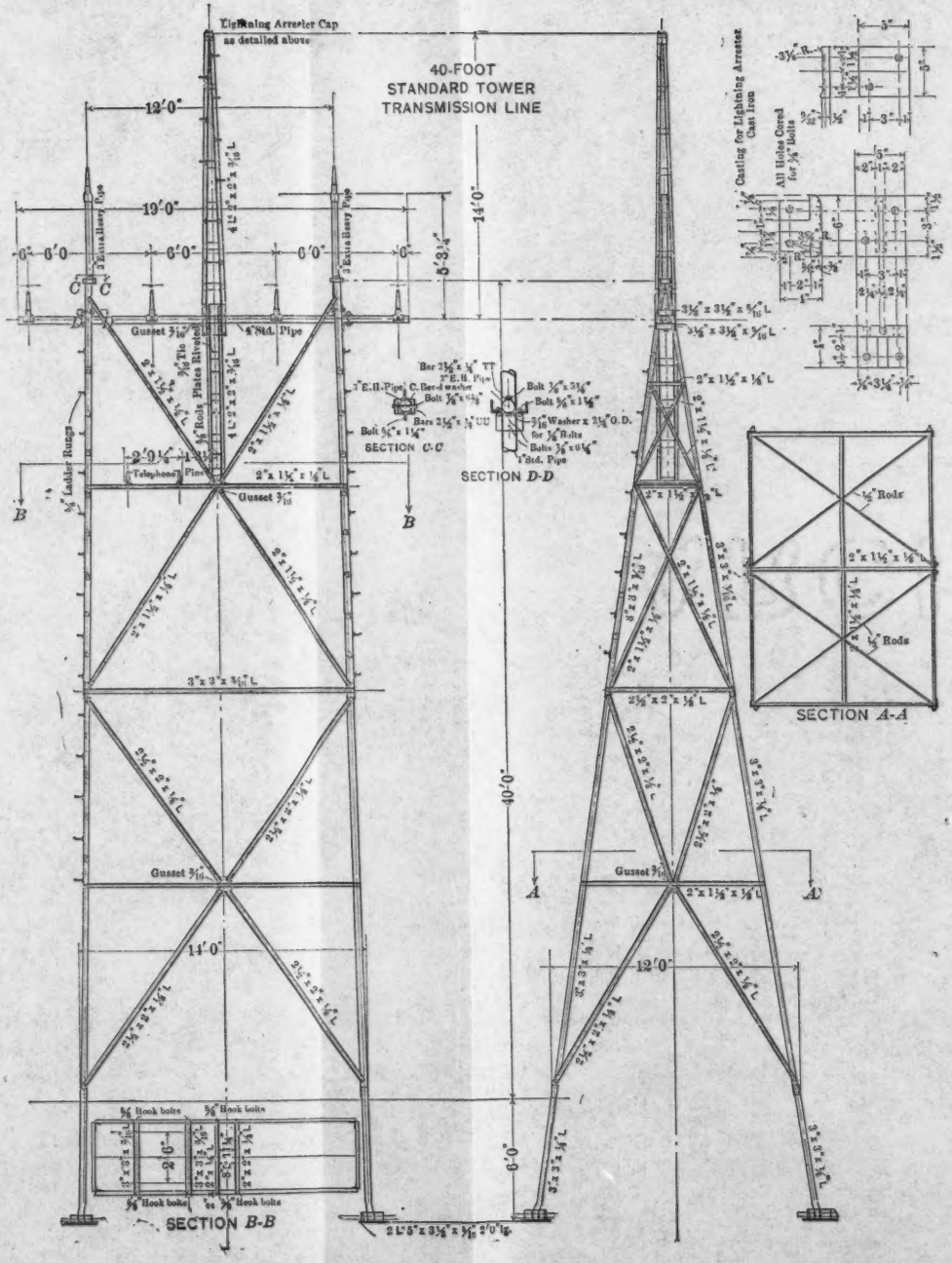
*Transmission Lines.*—Four 60 000-volt power transmission circuits and two tower lines have been built from the power-house to

the City of Mexico, and two circuits from the City to El Oro, as shown on the map, Fig. 4. They are carried by steel towers, on each of which are two circuits of 168 000 cir. mils, copper cable, equivalent in cross-section to No. 000 B. & S. gauge wire, supported on porcelain insulators 14 in. in diameter. The towers for the transmission line are built up of steel angles, all parts being heavily galvanized after all machine work had been completed. Plate CIII shows the dimensions of the standard tower, and the photographs, Figs. 1 and 2, Plate CX, illustrate the line construction. The towers are 58 ft. high, over all, the feet being set 6 ft .in the ground. The cables are supported 40 and 46 ft. above the ground, the conductors forming two equilateral triangles with 6-ft. sides. A 14-ft. extension in the center of the tower carries a galvanized-steel cable with lightning arrester, and protects the electrical apparatus from damage. The towers will stand a horizontal side strain of 1 650 lb. at each insulator, or 10 000 lb. altogether. The standard distance between supports is 500 ft., but spans up to 1 500 ft. are made with higher towers having greater strength.

In tropical countries the use of wooden poles is objectionable on account of their short life, and in Mexico the cost is also excessive as they must be imported from abroad. The substitution of steel not only reduces the first cost, but also gives a strong, permanent and fire-proof construction, making the line much less liable to interruption. Towers can be handled more conveniently than poles in a mountainous country without roads, as they can be knocked down and packed in light bundles for mule-back transportation and then readily assembled at the points where they are to be erected.

With long spans the smaller number of insulators is also an advantage, in that it permits larger and safer insulators and the use of higher potentials than is possible with short spans. The insulators are made in three parts, which are shipped separately and cemented together on the ground in Mexico. Each part is tested before shipment by subjecting it while wet to a test potential of 60 000 volts. After being assembled they will withstand a potential of 120 000 volts. The insulator pins are 15 in. long, and are made of 2-in. steel pipe set in drop-forged sockets, which in turn are mounted on a 4-in. pipe cross-arm for the lower conductors, and on

PLATE CIII.
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SECTION OF TRANSMISSION LINE

FIG. 4.

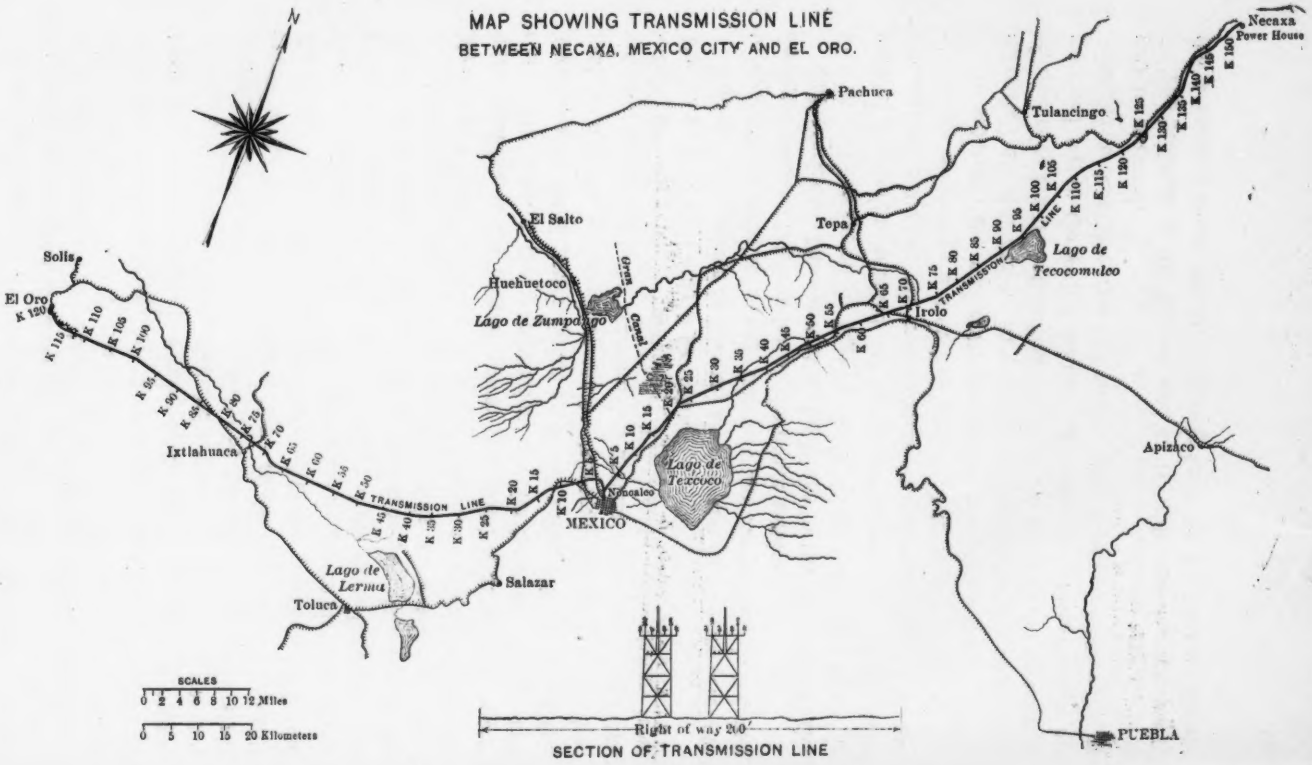

MAP SHOWING TRANSMISSION LINE
BETWEEN NECAXA, MEXICO CITY AND EL ORO.
N
Necaxa
Power House
Pachuca
Tulancingo
El Salto
Tepa
Lago de
Tecocomulco
Solis
El Oro
Huehuetoco
Lago de Zumpango
Irolo
Ixtlahuaca
TRANSMISSION LINE
Lago de
Texcoco
Apizaco
MEXICO
Lago de
Lerma
Salazar
Toluca
PUEBLA
SCALES
0 2 4 6 8 10 12 Miles
0 5 10 15 20 Kilometers
Right of way 20'
SECTION OF TRANSMISSION LINE

FIG. 4.

a 3-in. pipe extension for the upper ones. The pins are set in the insulators with Portland cement.

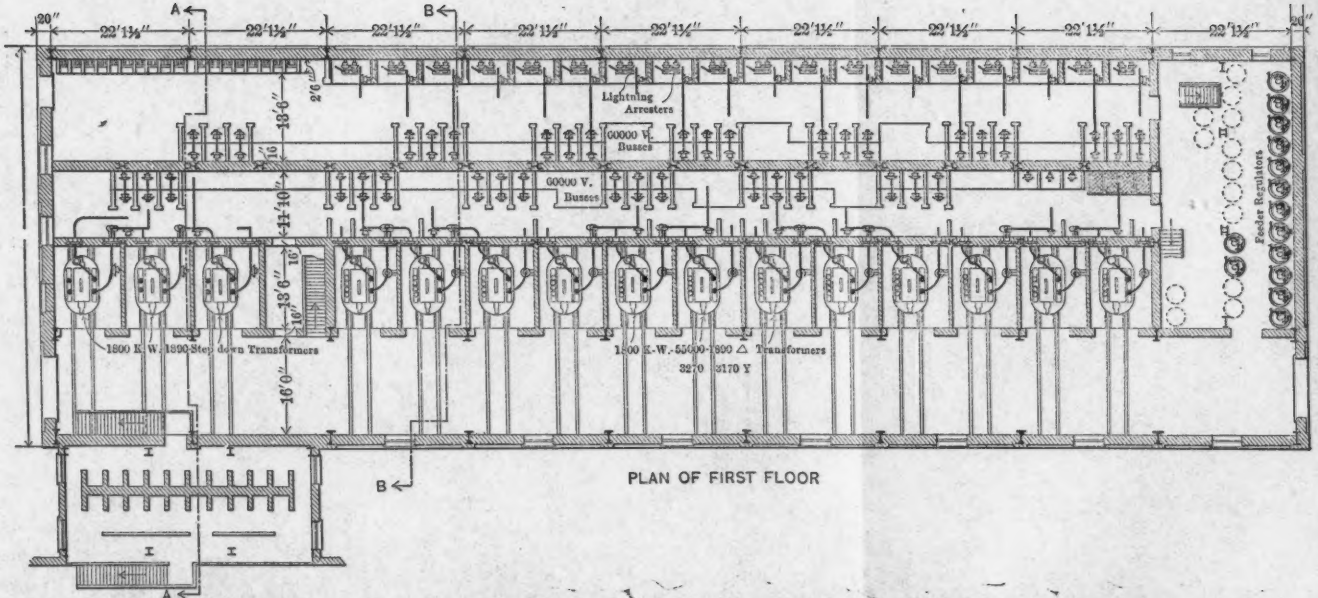
The conductors are six-strand copper cables, ½ in. in diameter, with hemp centers, and have a strength of 60 000 lb. and an elastic limit of 40 000 lb. per sq. in. The cable is shipped in lengths of 3 000 ft., and the joints are made with an 18-in. twisted copper sleeve. The stress on the cables and supporting structures was calculated by assuming a wind velocity of 100 miles an hour at right angles to the line, and allowing a stress in the materials of one-half the elastic limit. The cables are attached to the insulators by bolted clamps, no tie wires being used. Duplicate telephone circuits of No. 10 copper or steel wire are erected on each of the tower lines, and are placed 10 ft. below the high-potential cables on porcelain insulators.

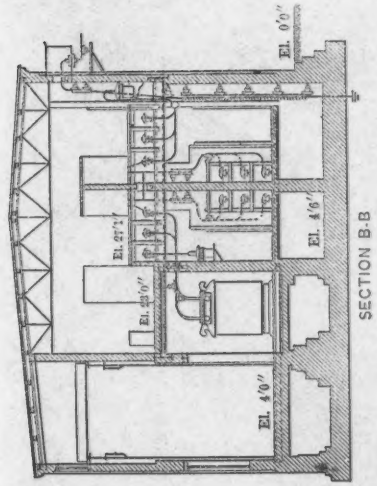
The distance from Necaxa to Mexico is 94 miles, and from Mexico to El Oro 75 miles. The total length, therefore, will be 169 miles, making it the longest power transmission in regular operation. The loss in the transmission circuits between Necaxa and Mexico, with 100% power factor at 60 000 volts, will be 8% at full load, so that the entire power can be delivered over two of the four circuits, or one-half the transmission system, with only 16% loss, should the other half be disabled. The loss in transmission from Mexico to El Oro is only 5 per cent.

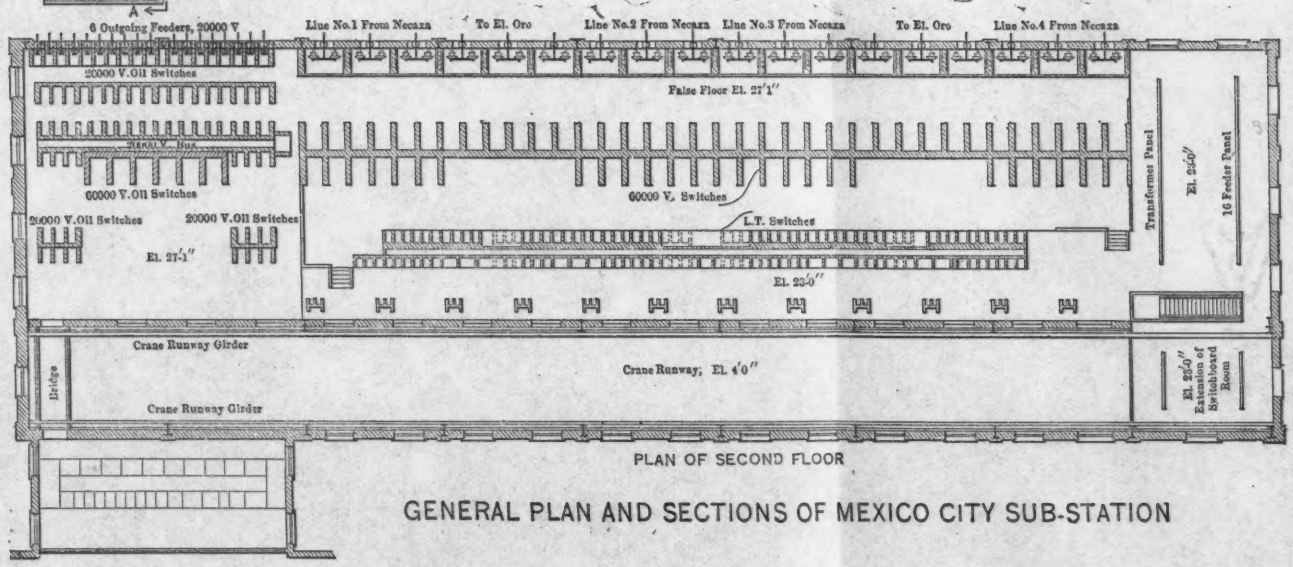
The circuit breakers at Necaxa, Mexico, and El Oro are arranged to cut out automatically any transmission circuit which becomes damaged without interruption to the power service.

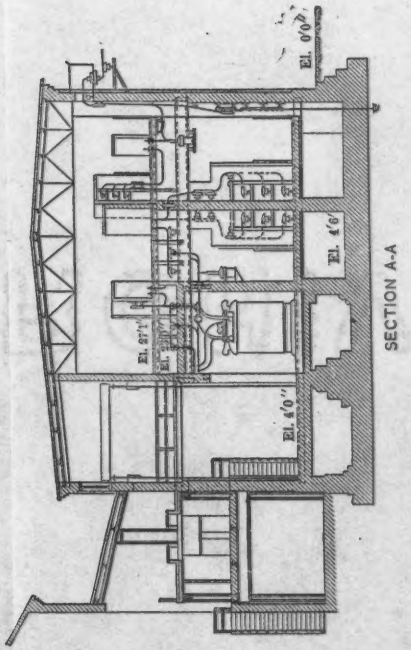
*Sub-Stations.*—The sub-station buildings in the Cities of Mexico and El Oro are shown in Figs. 1 and 2, Plate CXI, and follow in general the design adopted for the power-house. In Mexico there are sixteen 1 800-kw. oil transformers in separate fire-proof compartments covered by a traveling crane. The switches and wiring are in separate cells, and every precaution has been taken to isolate all parts from each other. In addition to the high-tension apparatus, an extensive low-potential feeder system for the city distribution is provided for in the switch-board. The step-down transformers are arranged to furnish current at either 1 500, 3 000, or 6 000 volts, as may be required.

The building is 203 ft. long and 65 ft. wide, and is near one of the company's steam plants, originally built by the Siemens-Halske




GENERAL PLAN AND SECTIONS OF MEXICO CITY SUB-STATION



Company. In addition to this there are three other steam central stations in Mexico, aggregating 20 000 h. p., which are now entirely or partially shut down by the cheaper power from Necaxa.

At El Oro, a sub-station, 115 ft. long, and 59 ft. wide, has been erected. This is similar to the one in Mexico, and the nine 1 800-kw. step-down transformers installed there are duplicates of those in the latter city.

The distribution to the gold and silver mines of the El Oro and Tlalpujuhua districts is at 3 000 and 6 000 volts.

An extension of the transmission system to Pachuca is now under way.

The original hydraulic plans of the Necaxa development were made by H. L. Cooper, M. Am. Soc. C. E., who also had charge of the construction in Mexico up to 1905. The work is now being conducted under the direction of Albert Carr, M. Am. Soc. C. E., as Manager of Construction, with Mr. Walter Diem as Resident Engineer and Mr. F. S. Hyde as Hydraulic Engineer. J. D. Schuyler, M. Am. Soc. C. E., is engaged as Consulting Engineer in connection with the construction of the hydraulic-fill dams. Mr. R. F. Hayward has charge of the operation of the plant and the completion of the electric installation.



FIG. 1.—TENANGO FALLS, MEXICO.

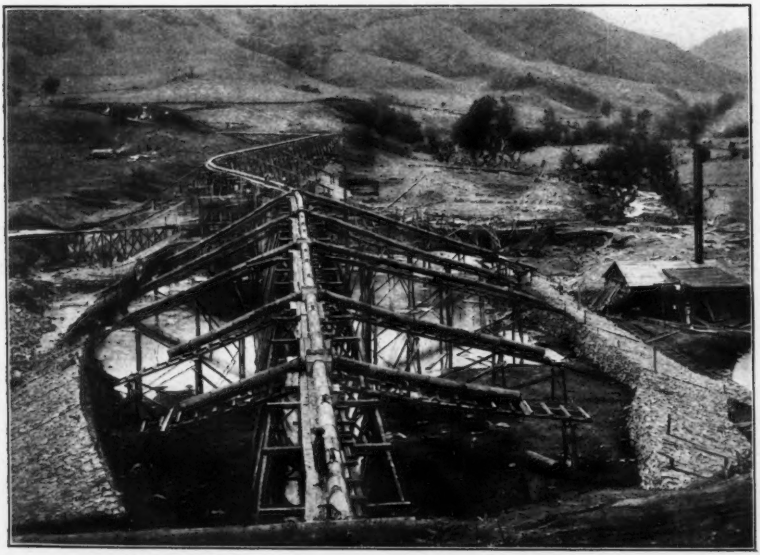


FIG. 2.—DAM NO. 1 ON THE TENANGO RIVER, LOOKING NORTH.

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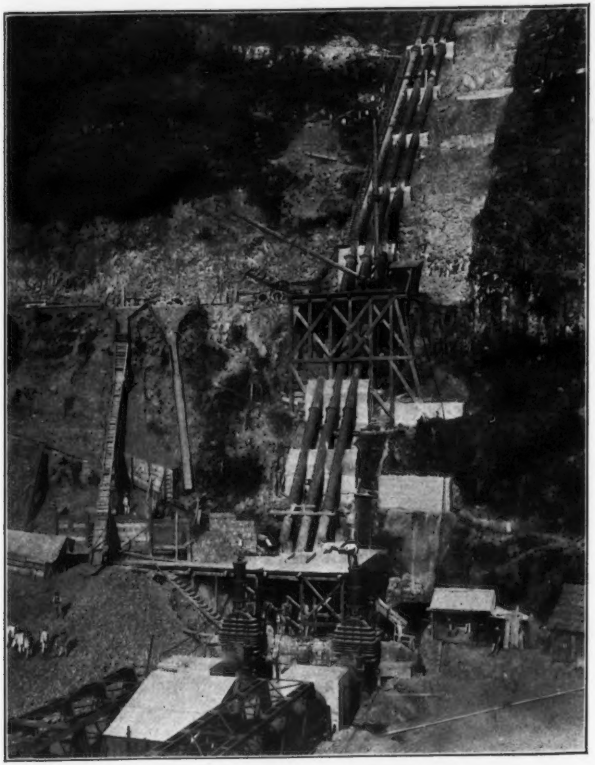


FIG. 1.—RECEIVER AND VALVES AT TUNNEL NO. 3.



FIG. 2.—PIPE LINE FROM POWER-HOUSE.

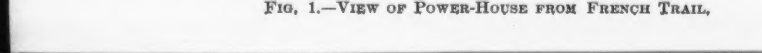


FIG. 1.—VIEW OF POWER-HOUSE FROM FRENCH TRAIL.

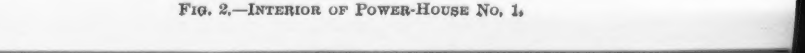


FIG. 2.—INTERIOR OF POWER-HOUSE NO. 1.

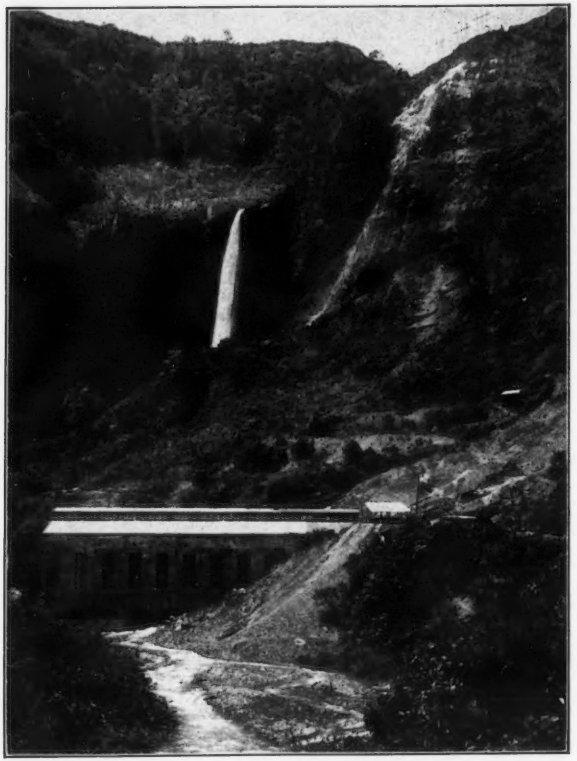


FIG. 1.—VIEW OF POWER-HOUSE FROM FRENCH TRAIL.



FIG. 2.—INTERIOR OF POWER-HOUSE NO. 1.

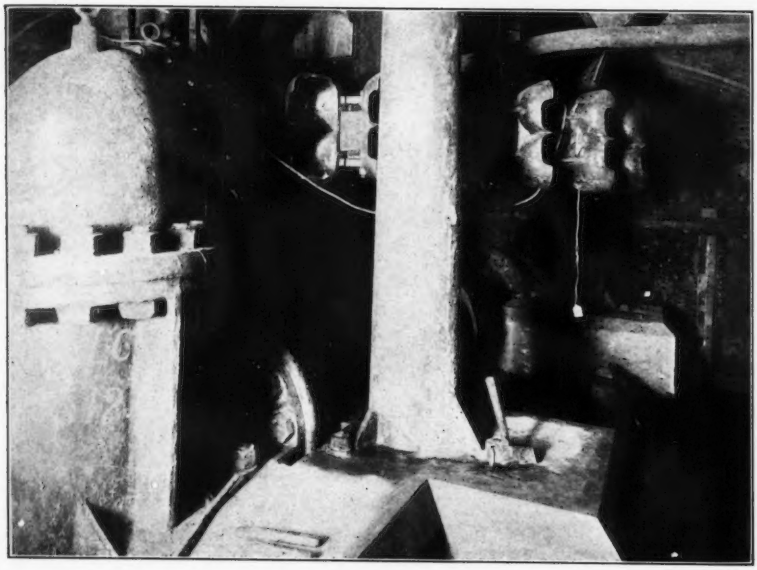


FIG. 1.—WATER WHEEL.

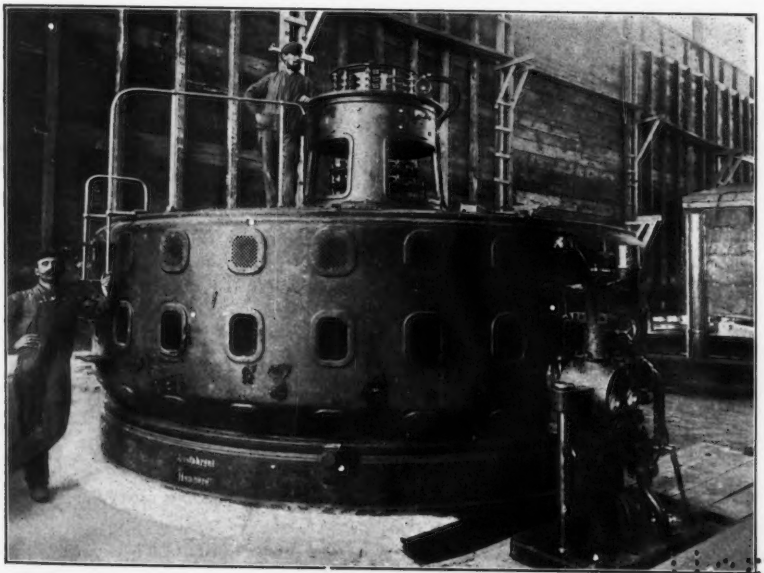


FIG. 2.—GENERATOR.

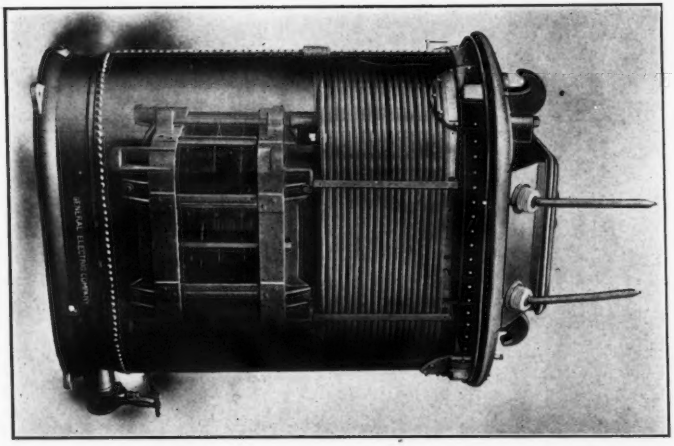


FIG. 1.—TRANSFORMER.

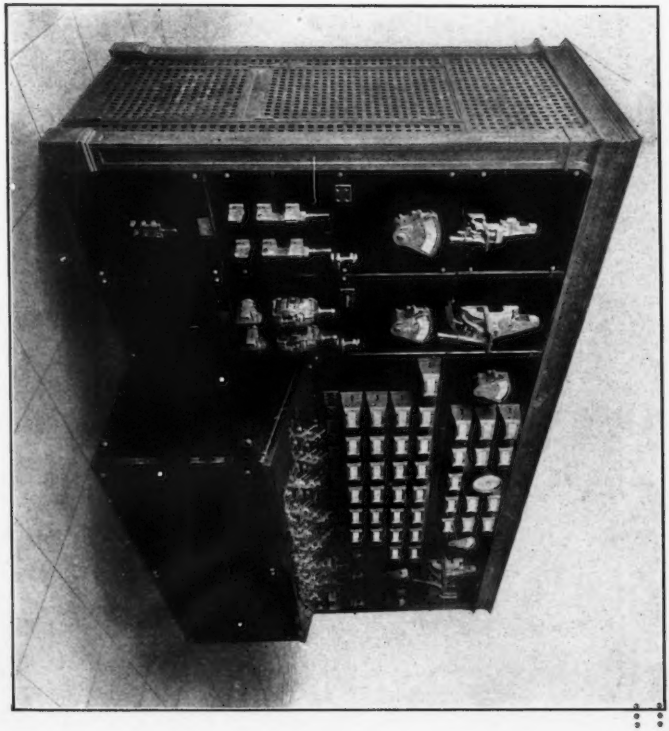


FIG. 2.—SWITCH-BOARD.

Mod

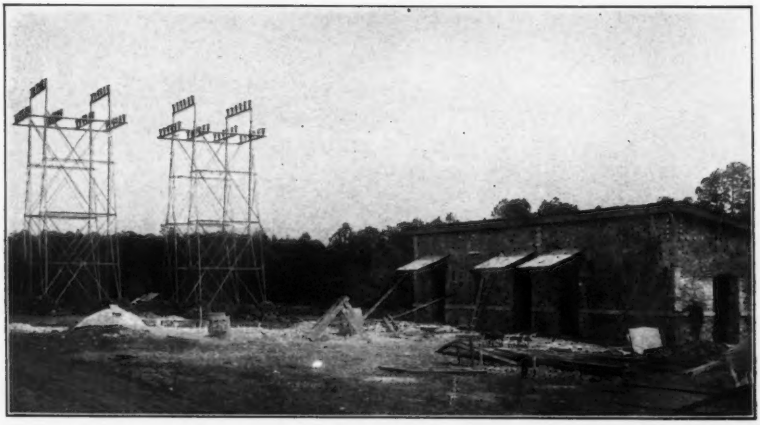


FIG. 1.—PATROL HOUSE AT CARMEN.

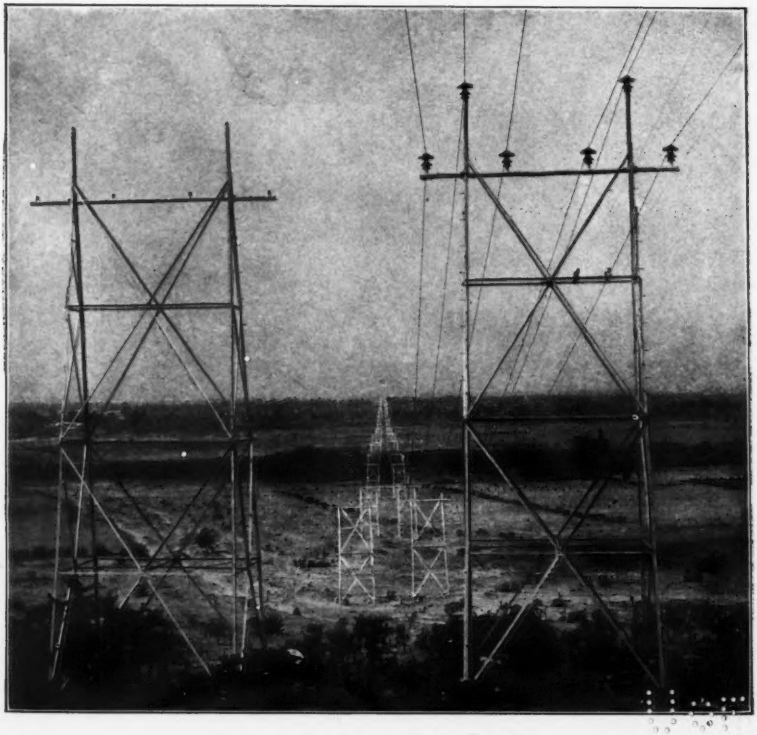


FIG. 2.—NECAXA LINES TOWARD MEXICO.

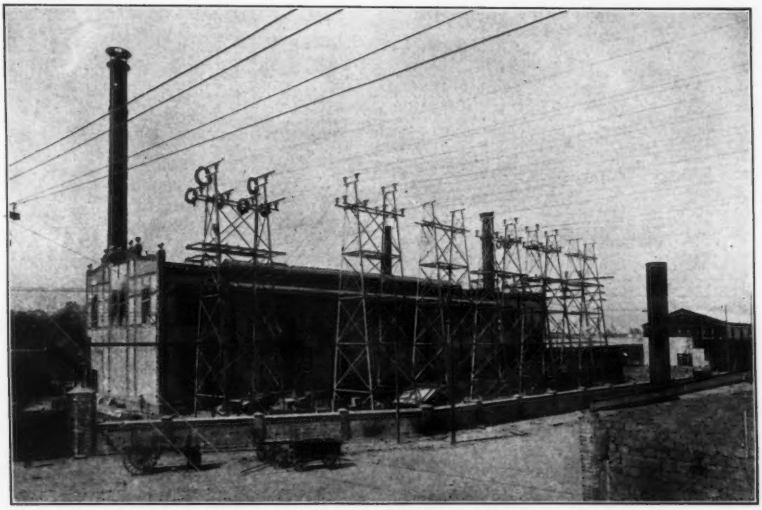


FIG. 1.—SUB-STATION AT MEXICO.

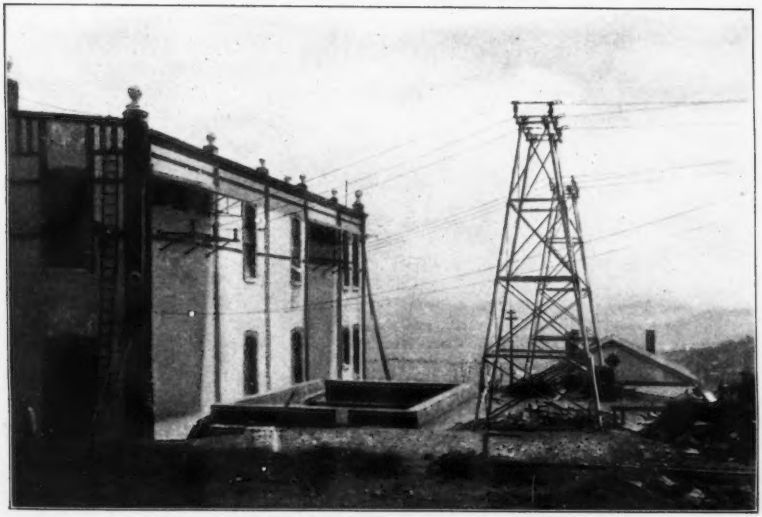


FIG. 2.—SUB-STATION AT EL ORO.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## CONCERNING THE INVESTIGATION OF OVERLOADED BRIDGES.

### Discussion.*

BY MESSRS. R. D. COOMBS, MANSFIELD MERRIMAN, HENRY B. SEAMAN AND GEORGE B. FRANCIS.

Mr. Coombs. R. D. COOMBS, ASSOC. M. AM. SOC. C. E. (by letter).—The writer hopes that the discussion of this paper will bring out the various methods used in treating old railroad bridges, particularly with regard to unit stresses and impact allowances.

It does not seem to be consistent, when figuring new work, to claim that the "300 formula," for instance, represents closely the actual conditions, and to refigure old bridges by a reduced impact.

Unless a "stop order" is issued, the impact load exists equally for old and new structures, assuming no excessive vibration or deflection in the former. The variation will then appear in the unit stresses, the question being the relation of the existing stress to the elastic limit. It would be interesting to know whether the rigid adherents of the "300 formula" request a "stop order" at bridges whenever the unit stresses amount to 75% of the elastic limit. The writer's preference is for the following method, using the impact curve marked *A* in Fig. 1:

*First.*—Calculate the existing stresses from the drawings, when obtainable, otherwise take field measurements of the structure.

*Second.*—Examine the structure for corrosion, net area, loose rivets, wear at joints, excessive vibration or deflection, and re-

* This discussion (of the paper by Wilbur J. Watson, M. Am. Soc. C. E., printed in *Proceedings* for April, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Coombs.

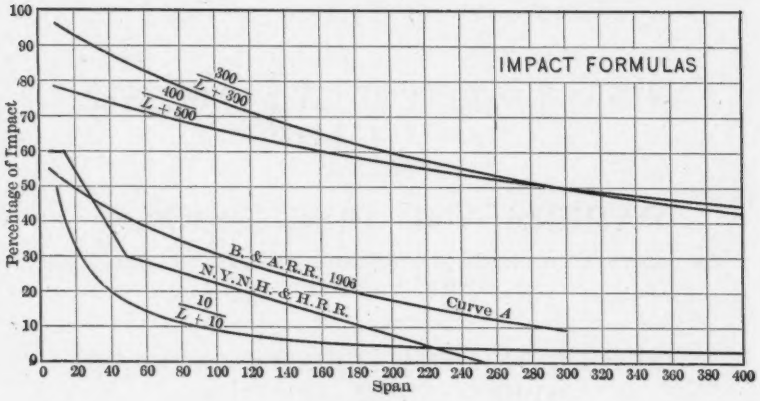



FIG. 1.

versed or eccentric loading, paying especial attention to points found when figuring from the drawings.

*Third.*—Revise the figured stresses, if necessary, as a result of the field inspection, and then examine the results with reference to the figures in Table 2.

Regarding the author's recommendation as to the effective depth of plate girders, the writer is of the opinion that ordinarily it will make little practical difference which effective depth is used.

TABLE 2.—MAXIMUM UNITS FOR OLD STRUCTURES.

(The figures are for both dead and live loads.)

| Kind of material. | Elastic limit. | Tension and compression. 0.60 × E. L. | Shear. $\frac{3}{4}$ × 0.60 × E. L. | Bending. 1 × 0.60 × E. L. | Bending pins. $\frac{4}{3}$ × 0.60 × E. L. | Shop Rivets. Shear. $\frac{3}{4}$ × E. L. | Shop Rivets. Bearing. $\frac{4}{3}$ × E. L. | Field Rivets. Shear. $\frac{3}{4}$ × 0.75 × E. L. | Field Rivets. Bearing. $\frac{4}{3}$ × 0.75 × E. L. | Rollers. |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 000 to 68 000 | 33 000 | 26 500 | 17 600 | 27 000 | 35 200 | ..... | ..... | ..... | ..... | 1 000 D. |
| 56 000 to 64 000 | 30 000 | 24 000 | 16 000 | 24 000 | 32 000 | ..... | ..... | ..... | ..... | 900 D. |
| Soft steel | 25 000 | ..... | ..... | ..... | ..... | 16 650 | 33 300 | 12 500 | 25 000 | ..... |
| Wrought iron. | 20 000 | ..... | ..... | ..... | ..... | 13 300 | 26 600 | 10 000 | 20 000 | ..... |

MANSFIELD MERRIMAN, M. AM. SOC. C. E.—This paper contains sound doctrine, and calls attention to a subject which is becoming of greater importance every year. Numerous highway bridges are now overloaded, owing to the addition of sidewalks and trolley tracks, so that the stresses in the members are much higher than intended by the designers. The speaker has in mind a wrought-iron bridge, built about thirty years ago, with one footwalk, the truss on that side being made heavier than the other one. A second footwalk and a trolley track have been added on the same side as the lighter truss, so that the load brought upon it is about 60% heavier than that intended, while the floor system is so highly stressed as to be likely to fail under full load. Mr. Merriman.

The concluding paragraph of the paper deserves especial notice, as giving principles which always should be observed, but are often violated. Under no circumstances can it be allowed, in investigating a bridge, to use the drawings which were prepared by the designer or manufacturer, for it cannot be assumed that the bridge was built in conformity with those drawings. Specifications for the design of bridges have also little applicability in deciding whether or not an existing structure should be condemned. Even in repairing or strengthening an old bridge, rules and specifications are materially different from those used in design, especially when the repairs are only intended to lengthen the life of the bridge for two or three years.

The author makes no reference to pins, but it will often be found that they are very highly stressed in old highway bridges to which a trolley track has been added. It is the speaker's opinion that higher bearing and flexural stresses may be permitted on these pins than in any other part of the truss, since the failure of a pin appears to be very rare. It should be noted, however, that there must be a considerable distortion by bending in such pins, and that this affects the distribution of the stresses in the eye-bars whenever there are more than two bars in one panel, so that some of the eye-bars may receive stresses much higher than they are supposed to have, under the usual assumptions.

HENRY B. SEAMAN, M. AM. SOC. C. E.—The key to the rational investigation of overloaded bridges would be a formula for the dynamic increase of live-load strains which will give a strain equivalent in effects to that of quiescent or dead load. Such a formula has not yet been discovered, and probably never will be; but, if such could be obtained, it would seem to be entirely safe to permit 20 000 lb. per sq. in. on structural steel of 60 000 lb. ultimate strength, and when the bridge is under constant supervision it would seem to be permissible to increase this to, say, 24 000 lb. per sq. in., the allowable strains on wrought iron and on a higher steel to be modified accordingly. Mr. Seaman.

Mr. Seaman.

The author refers to the formula, $I = L \frac{L}{L+D}$, as a rational impact formula, but does not explain its rational deduction. Any formula containing $D$ (dead load) would not seem to be an impact formula, although it might be an empirical formula for dynamic increase, which would include impact, oscillation, fatigue, "ignornance," etc. As far as the speaker has been able to ascertain, the proper form of an impact formula should be: $I = \frac{C'}{\sqrt{L}}$, in which $L$ is the distance traveled by the load, in producing the given strain, and equals approximately one-half the span; and he was advised some years ago by B. W. Guppy, M. Am. Soc. C. E., that a value of $\frac{9}{10}$ for the constant $C'$ would conform approximately to the experiments made by E. Herbert Stone, M. Am. Soc. C. E. As this formula is based upon the assumption that the strain produced by a load instantaneously applied is double that of the same load at rest, and also that the effect of a suddenly applied load varies inversely as the time consumed in its application, the value of $I$ would be 100% for a very short span, and would thence decrease to zero for a span of 0 ft., provided the speed of the train was constant. The impact for the shortest spans would not be less than 100%, however, as the speed may decrease.

If this formula for impact were enlarged to cover the entire dynamic increase of an applied load, another constant, $C''$, should be added, making the formula: $I = \frac{C'}{\sqrt{L}} + C''$.

If this constant is intended to cover the effect of oscillation, its value would be replaced at from 30 to 50%, varying according to different authorities.* If it were also intended to cover the fatigue, "ignorance," etc., it would probably be further increased.

To the speaker's mind, such a modification of live-load strains is desirable, not merely for the investigation of old bridges, but also for the design of new bridges, except that, for old bridges, which receive constant supervision, the value of $C''$ might be less than would seem to be advisable in a new structure, subject to no special supervision, and to a possible increase of loading. The advantage of this method of design would be to produce heavy counters, and thus prepare for the increased weight of traffic which experience has shown may be expected.

The author suggests that more failures occur in compression members than in tension members; but, if such is the case, it would seem to be due to improper bracing, or to improper design of details, or possibly to accident, rather than to insufficient theoretical cross-section.

* *Transactions*, Am. Soc. C. E., Vol. XLI, p. 240.

Mr. Seaman. He mentions the usual assumption of the shearing strength of material as equal to two-thirds of the tensile strength, and suggests that this is too small. The speaker usually assumes the shearing strength of material as equal to three-fourths of the tensile strength, and the bearing strength as equal to one and one-half times the tensile strength. If, however, allowance is made for softer rivet steel, the corresponding modification might be made in the allowable strains.

The general subject of the investigation of overloaded bridges is an interesting one, and accumulated data and comparison of views are always of value. The theoretical analysis of a structure should be thoroughly made, and will aid, though it cannot replace, individual judgment.

A number of years ago, in the early days of iron bridges, the speaker was called upon to examine a deck-truss, revolving drawbridge, reported to be in dangerous condition. He examined the drawings and records of the structure, and learned that the bridge had already been condemned twice by different engineers. In examining the structure it was found to have been built in accordance with the drawings, but to have had two accidents, due to vessels striking the bridge when closed. The fractures thus caused were carefully and properly spliced, but the main tension diagonals were so slack that they were spread apart by blocks of wood in order to bring them in tension. The counter diagonals were tight, and apparently doing service. Recalculation of the bridge showed that the sections were sufficient for the loading, and the speaker ventured to suggest that the bridge needed readjustment.

A roadmaster and track gang were placed at his disposal, the wooden blocks were knocked out, and the men were instructed to unscrew the counter rods. When one of these rods was unscrewed 1½ in. the men refused to do further work, fearing that the bridge would fall. The foreman was thereupon called to the center pier and told to look over the new line of the chord. He was amazed and delighted, and the further adjustment continued without objection. The bridge was thereafter reported in first-class condition until replaced several years later by a double-track structure.

This instance is cited merely to show the advisability of careful investigation and thoughtful study as to causes of deformations and apparent weakness, and also as an assurance that reliance should be placed upon theoretical deductions, carefully made.

Mr. Francis. GEORGE B. FRANCIS, M. AM. SOC. C. E.—About five years ago the speaker was Chief Engineer of a street railway having 270 miles of track, operating in eighteen different communities. At the time of accepting the engagement, one of the first things the speaker tried to ascertain was the condition of the various bridges over which the road was operated.

Mr. Francis.

Among the papers of the company no very complete record of the condition, characteristics, or systematic inspection of these bridges could be found, and it might interest the members to know what was done in getting together some useful data and establishing a method of inspection.

There were about 135 bridges: Some had been built for streets and highways by the various municipalities and towns; some by existing steam railroads, over their tracks on which the highways and street railways were located; some built on private right-of-way by the street railway company; and some built on highways by the street railway company. These embraced all classes of structures.

One of the first things done was to make a list showing their general characteristics, the date they were built, who built them, who was the owner, and who was under obligation to strengthen, renew, or repair them.

Then a frequent and practical examination was instituted, and a record made, so that, in case of trouble, it would be possible to go before a court and testify that the bridges were being looked after in a systematic way.

A good many of these bridges were strengthened in consequence of this examination. On one of the routes, a regular steam railroad freight car service was maintained, the freight cars being hauled by electric locomotives. The bridges on this line were built or strengthened for corresponding loads. On other lines there was the usual street car equipment and also a heavy type of electric interurban car. This latter type was the one considered for loads in making calculations for strains. If the tensile strains in the iron or steel did not exceed 20 000 lb. per sq. in., the bridges were considered safe; if the strains were greater, the bridges were strengthened. In most cases the greater strains occurred in the floor stringers, and various expedients were adopted to insert new members. Generally, the steel bridges were found to be strong enough, except as stated.

A good many minor structures of wood and stone were in all stages of repair, and were quite easily strengthened. There was considerable trouble with the various owners as to the division of expenses and the manner of doing the work. As a rule, the expense of strengthening fell upon the street railway company.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## THE VENTILATION OF TUNNELS.

### Discussion.*

BY MESSRS. GEORGE S. RICE AND R. P. BOLTON.

Mr. Rice. GEORGE S. RICE, M. AM. SOC. C. E. (by letter).—Mr. Churchill has referred to the conditions in the New York subway. At a later time the writer hopes to present to the Society a comprehensive paper on this subject. At the present time, however, it seems proper to mention a few facts concerning the "so-called ventilation" of the subway. The words "so-called ventilation" are used advisedly, because there seems to be a very general misconception of the subway problem.

Heretofore, the objectionable conditions which have prevailed in underground railroads have been due mainly to the vitiation of the air by locomotives. The conditions were improved by providing mechanical means for removing the bad air and replacing it with fresh air from the outside. When electrical motors were substituted, all except a few thousandths of 1% of the foul air was at once removed. It only remained to supply enough fresh air for the consumption of the passengers. To accomplish this, the train movement was depended upon, in seven of the nine subways which have been constructed in America and abroad.

These roads were so near the street surface that it was thought that ample renewal could be obtained from the piston action of the trains. Where the roads were short, or the cross-sections large, and the openings into the outside air numerous, the results have

* This discussion (of the paper by Charles S. Churchill, M. Am. Soc. C. E., printed in *Proceedings* for August, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Rice. been good, notably in Berlin and Paris. In most other cases, experience has indicated that wholly satisfactory conditions cannot be obtained in this manner. The tube roads are usually constructed as two single-track tubes, the trains thus traveling in one direction in each tube. Even under such favorable circumstances, the piston action of the trains has not produced a satisfactory air renewal, and mechanical ventilation has had to be resorted to.

The New York subway (the deep tunnel portions of the road are not referred to in this discussion) is near the street surface, its cross-section is large, and the openings are numerous. These conditions favor ample air renewal from train movement.

From careful investigations which have been made, it has been found that the subway air, when measured by the carbon dioxide standard, is all that could be desired. The average of more than 2 000 analyses of air samples taken in the streets, in the stations, in the subway between stations, and in the trains, shows: in the subway only 4.81 volumes of carbon dioxide in 10 000 volumes of air; in the streets, 3.67; difference, 1.14 volumes. The greatest amount found in the subway was 8.89 volumes in 10 000.

In winter it is to be expected that the air in the trains will sometimes be high in carbon dioxide. The car doors and windows are then closed, and often the guards cannot keep the ventilators open on account of objections from passengers. Under such circumstances, the same vitiation would exist if the trains were running in the open air. Therefore, such conditions cannot be charged to poor ventilation of the subway. But, on account of several peculiar characteristics, as a result of construction and operation, certain conditions have developed in this subway which do not exist to the same degree in any other subway or tube railroad now in operation. These characteristics and the resulting conditions are as follows:

*1.—The Large Amount of Heat Liberated in the Subway from all Sources, due to the Operation of Trains.*—During the summer of 1905, this heat approximated an average of 25 285 000 B. t. u. per hour, throughout the 24 hours, varying from 4 689 000 to 42 400 000 B. t. u. per hour, approximately.

The greater part of this heat is dissipated through the subway structure into the adjoining ground. A relatively small amount is carried out of the openings of the subway by the exhaling and inhaling action of the trains. About 93% is dissipated in these two ways. The remaining heat increases the subway temperature during summer to an average of about 6° greater than that of the outside air; or, approximately, to an average of 15° greater than the temperature in the subway before operation.

*2.—The Effect of the Subway Structure, in Location and Construction, upon the Heat Dissipation.*—The amount of heat dissi-

Mr. Rice.

pated through the subway structure is dependent upon the difference in temperatures between the subway and the ground around it—or heat head—the ground-water level, relative to the structure, and the conductivity of the structure. In summer, the temperature of the adjoining ground decreases with the increase of the depth of the subway below the surface. Ground temperatures at some distance from the subway, observed on August 31st, 1905, at noon, were as follows:

| | | | | | | |
|---|---|---|---|---|---|---|
| At | 2½ | ft. | below | the | surface, | 75° fahr. |
| " | 6 | " | " | " | " | 74° " |
| " | 10 | " | " | " | " | 72° " |
| " | 15 | " | " | " | " | 68° " |
| " | 20 | " | " | " | " | 66° " |
| " | 30 | " | " | " | " | 60° " |

At the same time the temperature in the subway at the nearest point was 86°, and the temperature of the outside air was 82 degrees.

Other things being equal, it appears that, with the same amount of heat being liberated in the subway, the heat head is greater the greater the depth of the subway below the surface. In consequence of this, more heat is dissipated and the interior temperature is lowered.

Ground-water, on account of its high specific heat and continual movement, maintains a relatively greater difference between the inside and outside temperatures, and thereby produces a cooler condition in the subway.

The conductivity of the structure is largely affected by the water-proofiing. It has been estimated that it reduces the conduction through the New York subway structure at least 33 per cent. Of the seventeen most important subway and tube railroads, only two are completely surrounded by a water-proofing envelope; eleven have no water-proofing at all, the other four are partly water-proofed. The New York and Berlin subways are wholly water-proofed. The subway portion of the former is 10½ miles long; of this, 6½ miles are four-tracked. At any time during the maximum operation, 231 cars are in the four-track portion of the subway, carrying approximately 23 000 passengers.

The Berlin subway is a two-track road; it is a little more than one mile long, and during maximum operation it contains only 12 cars at any one time, carrying 2 100 passengers.

Therefore, with regard to the heat condition, both in the amount generated and the loss through the structure, it can be said that no other underground railroad in the United States, in Great Britain, or on the Continent, is comparable with the New York subway.

Mr. Rice. *3.—The Iron Dust Liberated by the Wear of the Rolling Stock and Rails.*—This dust comes mainly from the brake shoes. Between the Brooklyn Bridge and Ninety-sixth Street Stations the brakes are applied about one-quarter of the total time consumed in the run of the local trains, and one-eighth of the total time of the express-train runs. More than 20 tons of these shoes are actually ground to dust in a month on the whole road.

From what has been said, it must readily appear that the subway problem is not simply one of ventilation, as ventilation is usually understood. If the air between the Brooklyn Bridge and Ninety-sixth Street Stations were renewed every 3 hours throughout the 24 hours, during the maximum day's traffic which has yet occurred, the carbon dioxide should not exceed 8 volumes on the average; or, half-hour renewals during the rush hours would maintain the same standard during that time. Such renewals would remove a material quantity of the iron dust, but would have a relatively small effect in reducing the temperature. No amount of air renewal could make the subway cooler than the outside air. In fact, with 3-minute renewals, the subway would probably be a degree or more warmer than the outside air at all times in summer.

To improve the conditions in the subway, construction is now under way to renew the air in the four-track portion about every 25 minutes, in addition to such renewal as now takes place, due to the exhaling and inhaling action of the trains. This is to be accomplished during the day by the train movement actuating movable louvers, or valves, and at night by motor-driven fans.

The louvers and fans are to be installed in ventilating chambers constructed at points midway between the stations. The air is to be exhausted from the subway at these points. The fresh air will come in at the stations, where about 5 000 sq. ft. of vault lights have been cut out and replaced with gratings to provide a large additional inlet opening.

Bringing about the renewal in this manner has several advantages. It is accomplished during the greater portion of the day by the train movement acting through the louvers, thereby reducing the cost of operation. At night, when the train movement is small, and the cutside temperature lowest, the fans remove the air, thereby cooling off the structure to some extent.

In case of accident stalling trains, or fire in the subway, the fans are available to provide fresh air, or to remove the smoke; the smoke being drawn away from the station points and thus preventing such an accident as occurred in Paris. The chambers also provide entrances and exits to the subway at points midway between stations.

When the work described is completed there will be a material

improvement in the subway, but it will not be cooler than the out- Mr. Rice.
side air. If the public insists upon a cool subway, cold air will have to be introduced. The method of air renewal outlined will enable this to be done in the most economical and satisfactory manner.

R. P. Bolton, M. Am. Soc. C. E.—This paper contains some Mr. Bolton.
very interesting lessons for all engineers, especially for those who are dealing with the ventilation of the New York subway. Special interest attaches to the proposed remedy for the defects in the present condition of affairs, which is generally felt to be almost intolerable. The apparatus now being installed is expected to improve the atmospheric condition of the subway by two means: First, the train action is to be depended upon to force the dense air out through louvers in side chambers, and at night fans are to force fresh air into the interior and displace the dense air. Train movement, however, has already demonstrated its inability to act as a motive agent, to any great extent, and it is hopeless to expect results from that source of air movement. The fans installed in the side chambers will, no doubt, effect beneficial results, if their proportions are sufficiently ample, and if they are run at all times.

It would seem that the lessons learned by experience in subways in other countries, the results of which are presented in this paper, could have been applied to the New York subway ere this. This whole subject was presented to the engineering world through this Society by Mr. Churchill, in 1904, in a very comprehensive manner, and, from the facts he had collated, he then urged the view that the New York subway would require the installation of special means of artificial ventilation, and so it appears that the end of the year 1906 is a very late date for the authorities to be engaged on this matter, and to be as yet undecided as to the methods and results. In the public interest, it might be hoped that the knowledge and energy of the author, who has so closely studied the subject, and has favored the Society with this paer, might be engaged upon the work, and be devoted to giving the public prompt relief.

With regard to the effect of the closely fitting trains in the underground tubes in London, the speaker's observations two years ago were that incoming trains pushed a considerable draft into the stations, the air moving up through the elevator shaft and streetways, but that the same air was drawn back when the trains reentered the tunnel; and he felt then, as he feels now, that train movement is by no means to be depended upon for effective air renewal in any kind of subway.

The subject of effective air replacement and the dilution of the dense and heated air in the tunnel is of very wide nature, and it is not possible without very full details and statistics of the various

Mr. Bolton. parts of the tunnel to point out the methods and capacities required to effect the desired improvement. It would be of much interest to learn something of the capacities of the fans now being installed in the New York subway and their relation to the contents of the part of the tunnel they are to affect.

While the subject of tunnel air dilution is shown by the paper to be a matter in which wide variations may exist, one feature appears to be common to all such lines of transit, namely, the proportionally defective condition of the atmosphere inside the cars.

This feature is nowhere more pronounced than in the crowded cars of the New York subway, and it has seemed to the speaker strange that no effort has been made to effect any improvement in this matter, as it would afford a very direct relief to the traveling public.

In point of fact, the discomforts of the public are not so much due to the condition of the air in the tunnel as to the aggravation of that condition inside the cars. The opening of the forward doors of the head cars of trains in the summer, which measure was ordered last year, has been greatly appreciated by many suffering travelers. The air may be heated and dense, and is undoubtedly deficient in oxygen and overcharged with $C\ O_2$, but its rapid movement through the car is pleasant and cooling. The effect, however, is lost in the following car, on account of the restricted area of the doors and vestibules. The open windows are not effective, as the air of the tunnel rolls over the surface of the sides of the car.

It is noticeable that these cars are provided with head vents of the same character as those on the cars of surface railroads, and these are as ineffective as elsewhere, and are equally unsuitable to the subway conditions.

There appears to be no practical reason why the cars should not be provided with ample air scoops, so that every car should be afforded a thorough air passage through it, which can be modified for winter conditions in such a way that the dilution of the interior atmosphere with $C\ O_2$, at least, may be kept, approximately, the same as the body of the tunnel.

The speaker's observations show that these interiors are often far worse in winter than even under summer conditions, on account of the closing of doors, windows, and vents, ineffective as the latter are.

The application of agitators to the car interiors might be a source of relief for winter conditions, but should be accompanied by a positive removal of the dense air from the lower part of the car interior, and its replacement by the lighter air from overhead.

One of the contributing sources of discomfort is the heating up of the car itself by the emitted heat of the motive apparatus and

brakes, the heat of the interior lighting, as well as the heat emitted by the passengers themselves. Mr. Bolton.

The course suggested, therefore, would relieve the difficulty and discomfort at the source, and has the advantage, over the extensive arrangements required to affect a change of the air in the tunnel itself, of a local simplicity and directness.

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# PAPERS AND DISCUSSIONS.

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## STREET TRAFFIC IN NEW YORK CITY, 1885 AND 1904.

### Discussion.

BY MESSRS. S. WHINERY, N. P. LEWIS, G. W. TILLSON AND CLIFFORD RICHARDSON.

Mr. Whinery.

S. WHINERY, M. AM. SOC. C. E. (by letter).—Records of street travel, such as those given by the author, possess a general interest to the student of urban life and development. To the municipal engineer, their chief, and practically their only, value consists in the evidence they afford of the service and endurance of street pavements.

While the relative durability of the several kinds of pavement used on the streets of American cities is by no means the controlling factor in comparing the merits of one pavement with another, it is yet one of very great importance. Considering its importance, it is surprising how few reliable and satisfactory data there are upon the subject. More capital is invested in street pavements than in any other department of municipal work, and the charges for pavement maintenance constitute, usually, the largest annual expenditure for any one public utility in municipal accounts. It would naturally be expected, therefore, that the relative economy of different street pavements would be studied carefully by municipal engineers, and that such experimental investigations would be conducted as would furnish the necessary data for an intelligent discussion of the subject.

It is now generally accepted among engineers—though not yet appreciated by the public—that, other things being equal, the

economic life of a pavement is measured by the quantity of travel it is capable of enduring before it is worn out, and not by its age in years. This being so, the important thing is to ascertain, as accurately as may be practicable, the service record of the various kinds of pavement in use, measured by some common standard which will permit of intelligent comparison of results. Here, as in other departments of scientific investigation to determine relative values, isolated observations that are not based upon, or not reducible to, uniform standards are comparatively worthless. However interesting they may be, and whatever they may suggest, they lack the one element that would make them practically useful. Unfortunately, this may be said of nearly all the few observations that have been made on street travel. Aside from their inadequateness, they are not comparable upon a common basis. Mr. Whinery

Until it is generally recognized that there is the same necessity for uniform methods and standards in this work as in other scientific and engineering investigation—as for instance in the testing of structural materials and the performance of boilers and engines—street censuses of travel will continue to possess very little engineering value.

The writer has long felt that the value to municipal engineers of adequate and properly conducted censuses of street travel would be so great as to make their cost a trifling consideration. In no other way can the travel-endurance value of the several kinds of pavement, under the varying conditions of actual service, be even approximately determined.

It is a field in which the municipal engineer finds at present no reliable data to guide him in one of the most important departments of his work. If it were conclusively established that of two varieties of pavement, approximately equal in other respects, one is capable of 25% greater endurance under travel, or, in other words, that its economic life was one-quarter greater than the other, the knowledge might well be worth hundreds of thousands of dollars to our cities.

The writer does not desire to discuss the subject in detail here, but wishes to call attention, first, to the very great value of properly conducted street censuses of travel, and second, to the importance of the adoption of standard units and methods of conducting such work. It would be well worth while for some technical society dealing with municipal engineering to appoint a committee to devise and formulate a standard code of rules and regulations for the guidance of those who may have opportunity or occasion to engage in such investigations.

N. P. Lewis, M. Am. Soc. C. E.—It is fortunate that Mr. Richardson has presented this paper to the Society, for, while interest Mr. Lewis.

Mr. Lewis. in the subject may be largely academic, such investigations, as pointed out by Mr. Whinery, will have a very practical value in their application to the study of the efficiency and wearing qualities of different kinds of pavement.

It seems remarkable that so little work of this kind has been attempted; but the engineers in responsible charge of the highways of large cities are exceedingly busy men, and have very little time for investigations of professional interest and value such as they would like to make. It is also strange that so little has been done in the United States to confirm or elaborate the observations made by General Greene in 1885.

It is amusing to see how writers on the subject of highways and their improvement have been copying and incorporating in their books and papers, year after year, the old tables showing the results of the observations of Hayward and others of the traffic on London streets, and on those of Paris—observations which were made a generation or more ago. These old figures of the thirty odd thousand vehicles on the Rue de Rivoli have a very familiar look, and may be found in almost every book on the subject. Whether they have ever been verified the speaker does not know, but Mr. Richardson has stated that he made some observations, or had some made, recently in Paris, and that the number of vehicles did not come up to the old figures given for the Rue de Rivoli.

It will be noticed that the observations described by Mr. Richardson extended over two days on the New York streets, with the exception of those on Fifth Avenue, which were continued for three days. He referred to the practice in Great Britain of taking observations for one hour on one day, another hour on the next day, at still another hour on the third, and so on. In the speaker's judgment, the most satisfactory and accurate results would be obtained by making observations, not on one day or two days—certainly not at different hours on succeeding days—but by continued observations extending over not less than one week.

Observations of that kind were taken on a number of streets in Brooklyn, N. Y., in January, 1896, and demonstrated very clearly the erroneous deductions which might be made from observations limited to one day or to a couple of days—certainly from those covering but an hour or two.

While the results of these observations (presented graphically in Fig. 1) have no special interest on account of the volume of traffic, they illustrate forcibly the sudden changes which may occur in the volume of such traffic, especially on asphalt pavements. It will be seen that, under normal conditions, there are noonday and afternoon maxima. On Monday, January 6th, which was an unusually cold day, with an average temperature of 4°, the volume of traffic

was somewhat irregular, with a decrease between 10 and 11 A. M., in addition to the customary lull which always occurs at about 1 P. M. On Tuesday, as the temperature rose the travel increased, but at 1.45 P. M. snow began to fall, and the line indicating the volume of traffic immediately fell in the most striking manner. Again, on Saturday, the snow had nearly all disappeared from the center of the roadway by noon, and it will be seen that, for the first time since the snow appeared, there was an afternoon maximum. Mr. Lewis.

It may be said that the variations indicated by this diagram are those of an extreme case, but they illustrate forcibly how the volume of traffic on asphalt or other smooth pavements is affected by local conditions, and lead one to question the accuracy of results obtained from observations lasting only one or two days.

TRAFFIC ON BEDFORD AVE. BETWEEN HANCOCK ST. AND HALSEY ST.

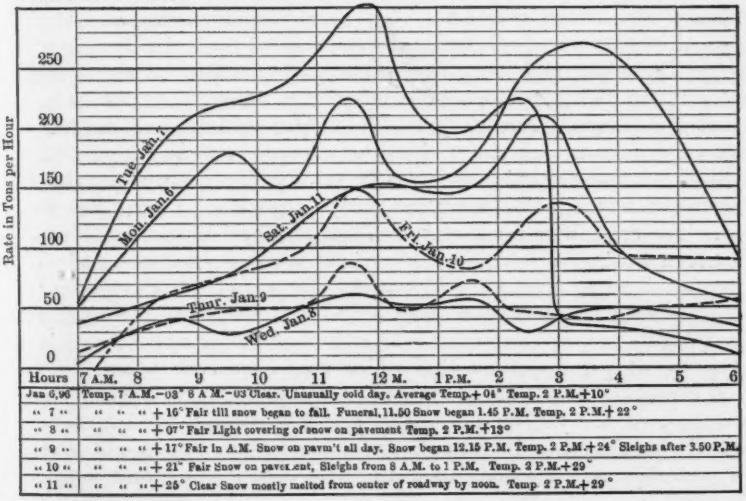



FIG. 1.

The classification of vehicles made by the author is quite minute, including vehicles of less than 1 ton, those from 1 to 3 tons, from 4 to 6 tons, and from 7 to 8 tons. In the observations made in Brooklyn, a simpler classification was used, but all horses were included, whether they were driven, ridden or led, and a careful record was kept of the falls, which was also a conspicuous feature of Mr. Hayward's London observations. These falls were classified as falls on the knees, falls on the haunches, and complete falls.

The author's data appear to have been collected by two men, an observer and a recorder. The observer, therefore, was obliged to assign to one of at least four classes more than 12 000 vehicles

Mr. Lewis. passing before him on Fifth Avenue in 11 hours; but the rate was by no means uniform, and it is more than probable that the rate of their passage at certain hours reached that of 2 000 or even 3 000 an hour. The recorder was also obliged to assign each of these vehicles to its proper column. This was an exceedingly difficult thing to do with any degree of accuracy, and, doubtless, there was a great deal of guessing and a large number of errors.

It is difficult to explain the extraordinary falling off in the traffic on Broadway, New York City. In 1885 this traffic was about 7 800 vehicles per day at Pine Street, while in 1904 it was found to be less than 3 300 per day between Franklin and Leonard Streets, and 3 771 per day between 18th and 19th Streets. This indicates a decrease of more than 50% in the number of vehicles using Broadway.

Possibly this can be explained by the fact that the side streets of lower Manhattan now have very much better pavements than they had twenty years ago, while the decrease of traffic in Broadway between Franklin and Leonard Streets might be largely accounted for by the widening and improvement of Elm Street; but, that there has been a decided decrease in the number of vehicles and the tonnage on Broadway appears to have been pretty well demonstrated.

In order that statistics of street travel may have any real value, a standard method of observation and compilation is most necessary. The committee on Standard Tests of Road Materials, of the American Society for Testing Materials, has discussed the desirability of securing data on street traffic, but, although the speaker was a member of the sub-committee which intended to investigate this subject, he has been unable to attend the conventions, and is not aware of any definite action which may have been taken.

The speaker would again emphasize the importance of such observations as the author has made, and his appreciation of their value in engineering investigations of pavements and roads, and the materials and methods used in their construction and maintenance.

Mr. Tillson. G. W. TILLSON, M. AM. SOC. C. E.—It is exceedingly interesting to find printed information about street pavements. Engineering literature is so wofully deficient in data regarding the forces that tend to destroy pavements that anything of the kind is doubly welcome to the engineer who is making specifications for or constructing them.

It seems to be a fact that, in making specifications for or laying street pavements, nearly all engineers are now using an old rule-of-thumb, the same as used forty or fifty years ago. An understanding of this subject, of course, is more necessary in designing asphalt than other pavements, and the author is about the only man who has been studying the matter systematically, and

applying his knowledge in such a way that he designs a pavement to meet the traffic conditions on the street. Mr. Tillson.

There are a great many difficulties in obtaining specific information of this kind. The way in which work is carried on—most of it by contract—does not give cities an exact knowledge of the cost of different pavements. A short time ago an attempt was made to decrease the expense of the pavement on some streets where it was known that the traffic would be light. To do this the wearing surface of the pavement—an expensive one—was decreased 12½ per cent. The result was that the price bid was just as high as when the full amount of wearing surface was required. It should be stated that this wearing surface was practically furnished by one party, and there was very little competition. The specifications were then changed, the full depth of wearing surface being stipulated, as it was thought that, if the full amount was to be paid for, the full depth should be obtained.

In studying these statistics, it is difficult to get the facts, in order to know the effect on the pavements, and some of the data in the paper illustrate this very well. The number of vehicles reported on Fifth Avenue was 12 000, and their tonnage a little more than 9 000, which gives a foot-tonnage of 246. On First Avenue, where the total number of vehicles was 6 000, or half as many as on Fifth Avenue, the tonnage was 13 000, or a little more than 299 tons per foot. From this it might be said that the two streets would require nearly the same kind of pavement; but, the character of the traffic should be examined. Of the 12 000 vehicles reported on Fifth Avenue, 50% were cabs with rubber tires, and each was drawn by one horse; 12% were automobiles with rubber tires, and were driven by their own power. On First Avenue, 3% of the entire number of vehicles were cabs, and 1% was automobiles. It can be seen, therefore, that if the effect of a 2-ton automobile on a pavement is compared with the effect of a 2-ton truck, and the same consideration is given to each, that the variable may be large.

It has always seemed to the speaker that a 2-ton vehicle drawn over a rigid pavement—such as granite or brick—would do much more damage if drawn at, say, 10 miles per hour than would a 4-ton truck if drawn at the rate of 3 miles per hour.

About eight years ago, Kent Avenue, in Brooklyn, was paved with granite on a concrete base, the blocks being the hardest that come to the New York market. This avenue is on the river front where one side of the street is lined with sugar packing-houses, and it was estimated at that time that 1 200 sugar trucks, each weighing, with its load, 8 or 10 tons, were driven over this pavement every day. All these trucks had to return, and, taking their weight at 2 or 3 tons, which is not excessive, it gives a tonnage of 14 000 or 15 000; and, as the roadway is only 34 ft. wide, in-

Mr. Tillson.

cluding street-car tracks, the tonnage was 450 tons per foot. Now, compare 450 tons on Kent Avenue, considering the character of its traffic, with 450 tons of the kind of traffic on Fifth Avenue, and it will be seen that the variable may be large.

Mr. Whinery's suggestion, to adopt some systematic method of taking these observations, is a very good one. In the United States, officials have been very backward in work of this kind, and it is a sad commentary on the foresight or enterprise of municipal corporations when the only information to be obtained regarding street traffic is that furnished by a commercial corporation. The only case known to the speaker where a municipal corporation attempted to investigate its traffic needs is that mentioned by Mr. Lewis.

There was one interesting feature of those needs which, perhaps, he forgot to mention, but which illustrates what is often found if the traffic on certain days and at certain hours is taken as the standard. On a certain day the curve ran very high, and upon inquiry it was learned that a very large funeral passed through the street at about that time.

Mr. Richardson.

CLIFFORD RICHARDSON, ASSOC. AM. SOC. C. E. (by letter).—Since the appearance of this paper, the writer has been privileged to spend five weeks in London, where he made some personal observations of the traffic, obtained many interesting data,* and became acquainted with a publication on the subject by Mr. Edgar Harper. In an article† entitled "Statistics of London Traffic," that gentleman has collected and published some extremely interesting data on the subject of vehicular traffic in the Strand, Holborn, and Piccadilly.

Additional data have also been collected in reference to traffic on the streets of New York, Boston and Chicago.

It appears that in the Strand, from 8 A. M. to 8 P. M., on July 4th, 1902, 11 982 vehicles passed, while more than a year later, on September 18th, 1903, during the same hours, there were 12 385. Of these vehicles, rather more than 4 000 were omnibuses.

In Holborn, for about the same periods, the total numbers of vehicles were 11 095 and 11 727, the number of omnibuses falling slightly below 3 000.

In Piccadilly, at Devonshire House, on a day in January, 1903, between 8 A. M. and 8 P. M., 16 064 vehicles passed, while on September 2d, 1903, only 13 875 passed; about 4 500 of these were omnibuses. Mr. Harper cites the fact that in July, 1865, only 8 220 vehicles passed the same point, during the same hours, thus showing a great increase of traffic.

Some of the interesting data from this report are contained in Table 9.

* Contained in Vol. 7 and 8, "Report of the Royal Commission on London Traffic."

† *Journal* of the Royal Statistical Society, Vol. 67, June 13th, 1904.

Mr. Richardson.

TABLE 9.—Comparison of Omnibus and Other Vehicular Traffic, in London.*

| Hour. | Number of Vehicles (Exclusive of Barrows and Cycles), Passing Both Ways Along: | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | The Strand (At Wellington Street). | | | | Holborn (At Southampton Row). | | | | Piccadilly (At Devonshire House). | | | |
| | Omnibuses. | Other vehicles. | Total. | Percentage of omnibuses to total vehicles. | Omnibuses. | Other vehicles. | Total. | Percentage of omnibuses to total vehicles. | Omnibuses. | Other vehicles. | Total. | Percentage of omnibuses to total vehicles. |
| 8 to 9 A. M. | 202 | 398 | 600 | 33.6 | 181 | 361 | 542 | 33.4 | 334 | 308 | 642 | 52.0 |
| 9 to 10 " | 365 | 538 | 903 | 40.4 | 270 | 465 | 735 | 36.7 | 400 | 496 | 896 | 44.6 |
| 10 to 11 " | 358 | 683 | 1 041 | 34.4 | 255 | 591 | 846 | 30.1 | 382 | 674 | 1 056 | 36.2 |
| 11 to 12 noon | 328 | 673 | 1 001 | 32.8 | 239 | 573 | 812 | 29.4 | 387 | 885 | 1 272 | 30.4 |
| 12 noon to 1 P. M. | 350 | 637 | 987 | 35.5 | 250 | 608 | 858 | 29.1 | 374 | 1 060 | 1 434 | 26.1 |
| 1 to 2 P. M. | 329 | 561 | 890 | 37.0 | 245 | 557 | 802 | 30.5 | 366 | 1 099 | 1 465 | 25.0 |
| 2 to 3 " | 344 | 575 | 919 | 37.4 | 243 | 552 | 795 | 30.6 | 384 | 937 | 1 321 | 29.1 |
| 3 to 4 " | 359 | 600 | 959 | 37.4 | 256 | 560 | 816 | 31.4 | 387 | 1 007 | 1 394 | 27.8 |
| 4 to 5 " | 369 | 677 | 1 046 | 35.3 | 239 | 617 | 856 | 27.9 | 369 | 1 026 | 1 395 | 26.5 |
| 5 to 6 " | 360 | 618 | 978 | 36.8 | 284 | 601 | 885 | 32.1 | 399 | 1 339 | 1 738 | 23.0 |
| 6 to 7 " | 356 | 517 | 873 | 40.8 | 247 | 569 | 816 | 30.3 | 394 | 905 | 1 299 | 30.3 |
| 7 to 8 " | 333 | 560 | 893 | 37.3 | 242 | 414 | 656 | 36.9 | 399 | 973 | 1 372 | 29.1 |
| Totals | 4 053 | 7 037 | 11 090 | 36.5 | 2 951 | 6 468 | 9 419 | 31.3 | 4 575 | 10 709 | 15 284 | 29.9 |

* From a paper by Mr. Edgar Harper, *Journal*, Royal Statistical Society, Vol. 67, June 13th, 1904.

Mr. Richardson.

On March 22d, 1906, an examination, extending over a period of 3 hours, was made of the traffic on the Thames Embankment, near Charing Cross, which showed that 2 158 vehicles passed, or at the rate of 8 632 vehicles for a period of 12 hours. Of this traffic, more than one-half were cabs and carriages, the remainder being vans, motors and carts.

On July 18th, 1906, the traffic on the Embankment, at Temple Avenue, as counted by the writer, amounted to 652 light vehicles and 328 heavy vans, etc., between the hours of 10 and 11 A. M., or at the rate of 11 760 vehicles in 12 hours. Between 4 and 5 P. M. 888 vehicles passed, or at the rate of 10 665 in 12 hours. The actual number passing during a 12-hr. period is undoubtedly much smaller, as the hours at which the count was made are those in which the traffic on the Embankment is greatest. It is probable, therefore, that the count of March 22d, 1906, represents more nearly the actual traffic on this roadway, which is constructed of macadam and is very difficult to maintain because of the heavy traffic.

The traffic on Piccadilly was counted by the writer on two occasions. Between 4 and 5 P. M. on July 17th, 1906, 1 344 vehicles passed Dover Street, or at the rate of 16 128 for a period of 12 hours. On July 19th, 1906, between 11.30 and 12.30 A. M., the count showed:

| | |
|---|---|
| Motor omnibuses | 108 |
| Motors | 124 |
| Cabs | 1 412 |
| Ordinary omnibuses | 480 |
| | 2 124 |

or at the rate of 25 488 vehicles in 12 hours.

These counts, like those on the Embankment, being made at the busiest time of the day, the daily traffic probably does not reach the high figures given for 12 hours, but it must be remembered that, in the fashionable season, the traffic on Piccadilly is extremely heavy at all hours of the day, and much greater than in January or September when the count given by Mr. Harper was made.

Mr. Harper has made no calculation of the tonnage of the traffic passing on London streets, but it is of interest to compare the data as to the number of vehicles, collected by him and by the writer, with the data for New York streets collected in 1904. In this respect, the traffic on Fifth Avenue is about as large as that on Piccadilly, as far as the number of vehicles is concerned, and is larger than that in the Strand or Holborn. If consideration is given to the fact that the traffic of London streets is largely made up of omnibuses, there can be no comparison as to the tonnage of the two, as the London traffic is much heavier.

From the point of view of the number of collars, the traffic on the two streets is, probably, very similar, and the wear and tear due to the impact of the horses' hoofs is quite the same. Mr. Richardson.

It may be of interest to remark here that the wood pavement on Piccadilly is replaced every five or six years, under this traffic, the blocks being removed when they have been reduced to a thickness of 3 in.

A very elaborate determination of the traffic of the various streets in London has been made under the auspices of the Royal Commission on London Traffic, and summaries of some of the most interesting results are presented in Tables 10 and 11.

The data in Table 10 are confirmative of the data in Mr. Harper's paper. Those presented in Table 11 show that at certain representative crossings the traffic is enormously greater, reaching nearly 30 000 vehicles in a period of 12 hours at Marble Arch and Hyde Park Corner. There is, of course, nothing in the United States to correspond to this, as far as known. The traffic in New York has not been taken at the busiest time of the year, at such intersections as Fifth Avenue, Broadway and Twenty-third Street, at Thirty-fourth Street, Sixth Avenue and Broadway; Thirty-fourth Street and Fifth Avenue; or Thirty-fourth Street and First Avenue. During the quiet months of July and August, counts were made at these places, the results being given in Table 12.

In a paper* read before the Commercial Club, of Chicago, in 1904, John W. Alvord, M. Am. Soc. C. E., gives some data in regard to traffic on streets in that city. The largest amount, as recorded by him, appears to be on State Street, where it is slightly in excess of 6 000 vehicles in 12 hours, and at times does not reach 4 000, as can be seen from the following figures:

TRAFFIC ON STATE STREET, CHICAGO, ILL. (ROADWAY 60 FT.).

| Date. | Hour. | Vehicles in 12 hours. |
|---|---|---|
| 10-2-03 | 9.15- 9.30 | 6 048 |
| 3 | 11.45-12.00 | 5 952 |
| " | 10.35-11.35 | 3 876 |

In Boston a recent count of the traffic by collars on several of the most heavily traveled streets gave the results shown in Table 13.

From these data it appears that the traffic in Boston on Devonshire Street, which is the heaviest one that was counted, is very much less than that on Fifth Avenue in New York, although the street itself is much narrower.

* "The Street Paving Problem of Chicago."

TABLE 10.—TRAFFIC IN SELECTED STREETS.*

| Street. | Goods Vehicles. | | | | Passenger Vehicles. | | | | Cycles and Barrows. | | | | Total Vehicles of All Classes. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day: 8 A. M. to 8 P. M. | | Busiest hour. | | Day: 8 A. M. to 8 P. M. | | Busiest hour. | | Day: 8 A. M. to 8 P. M. | | Busiest hour. | | Day: 8 A. M. to 8 P. M. | Busiest hour. | |
| | Number. | Per cent. of total. | Number. | Per cent. of total. | Number. | Per cent. of total. | Number. | Per cent. of total. | Number. | Per cent. of total. | Number. | Per cent. of total. | Number. | Number. | Per cent. of total during day. |
| Bayswater Road (West of Edgeware Road)..... | 2 832 | 24.0 | 181 | 14.7 | 7 274 | 61.5 | 817 | 66.3 | 1 710 | 14.5 | 234 | 19.0 | 11 816 | 1 232 | 10.4 |
| Oxford Street (East of Regent Street)..... | 3 778 | 27.0 | 349 | 26.0 | 8 192 | 58.5 | 913 | 67.7 | 2 043 | 14.5 | 85 | 6.3 | 14 013 | 1 347 | 9.6 |
| Cheapside (East of St. Paul's Church Yard.)..... | 4 436 | 35.3 | 505 | 38.2 | 6 108 | 48.6 | 600 | 45.4 | 2 019 | 16.1 | 217 | 16.4 | 12 563 | 1 322 | 10.5 |
| Adgate High Street (East of Minories)..... | 6 943 | 64.5 | 719 | 70.3 | 1 796 | 16.7 | 165 | 16.1 | 2 019 | 18.8 | 139 | 13.6 | 10 758 | 1 023 | 9.5 |
| Piccadilly (East of Hamilton Place)..... | 3 118 | 22.3 | 249 | 18.3 | 9 616 | 68.6 | 974 | 71.6 | 1 278 | 9.1 | 136 | 10.1 | 14 012 | 1 359 | 9.7 |
| Fleet Street (West of Ludgate Circus)..... | 2 916 | 32.7 | 282 | 32.8 | 4 933 | 55.2 | 487 | 56.6 | 1 083 | 12.1 | 91 | 10.6 | 8 932 | 860 | 9.6 |
| Victoria Embankment (West of Blackfriars Bridge)..... | 2 875 | 31.7 | 278 | 27.6 | 5 266 | 58.1 | 675 | 67.0 | 922 | 10.2 | 54 | 5.4 | 9 063 | 1 007 | 11.1 |
| Queen Victoria Street (East of Cannon Street).... | 3 382 | 27.4 | 379 | 28.4 | 7 780 | 63.2 | 870 | 65.3 | 1 157 | 9.4 | 83 | 6.3 | 12 319 | 1 332 | 10.8 |

* From "Report of Royal Commission on London Traffic." Table 6, Vol. 7, 1905, page 11.

Mr. Richardson.

It is proposed to continue the counts on all the streets which have been mentioned in this paper, and especially to determine the extent of the traffic at the prominent intersections in New York City.

TABLE 11.—NUMBER OF VEHICLES USING EIGHT REPRESENTATIVE CROSSINGS.*

| Points of observation. | NUMBER OF VEHICLES. | |
|---|---|---|
| | Per day of 12 hours. 8 A. M. to 8 P. M. | At busiest hour. |
| Marble Arch | (1) 29 320 | (1) 3 069 |
| Hyde Park Corner | (2) 29 286 | (2) 2 902 |
| Piccadilly, at St. James | (7) 20 474 | (7) 2 067 |
| Piccadilly Circus | (5) 27 050 | (4) 2 670 |
| Charing Cross | (3) 27 768 | (5) 2 642 |
| Strand, at Wellington Street | (8) 19 743 | (8) 1 821 |
| Ludgate Circus | (6) 22 956 | (6) 2 252 |
| Bank | (4) 27 523 | (3) 2 699 |

*From "Report of Royal Commission on London Traffic." Table 39, Vol. 7, 1905, page 55.

TABLE 12.—TRAFFIC ON NEW YORK STREETS—1906.

| Date. | Hour. | Street. | VEHICLES. Trucks. | VEHICLES. Cabs, Autos., etc. | Half hour. | 12 Hours. | Weather. |
|---|---|---|---|---|---|---|---|
| 8-13-06 | 9.44-10.24 A. M. | Fifth Avenue and Thirty-fourth Street. | 125 | 196 | 321 | 7 704 | Fair. |
| 8-13-06 | 3.05-3.35 P. M. | | 155 | 291 | 446 | 10 704 | Fair. |
| 8-14-06 | 3.45-4.15 " | | 141 | 277 | 418 | 10 032 | Fair. |
| 8-16-06 | 4.15-4.35 " | | 132 | 298 | 430 | 10 320 | Fair. |
| 8-24-06 | 2.35-3.05 " | | 112 | 242 | 364 | 8 736 | Threatening. |
| 9- 6-06 | 4.35-5.05 " | | 189 | 364 | 553 | 13 272 | Fair. |
| 8-24-06 | 3.15-3.45 " | Sixth Avenue, Broadway and Thirty-fourth Street. | 306 | 192 | 498 | 11 952 | Threatening. |
| 9- 6-06 | 2.15-2.45 " | | 263 | 197 | 460 | 11 040 | Fair. |
| 8-24-06 | 4.05-4.35 " | Fifth Avenue, Broadway and Twenty-third Street. | 240 | 195 | 435 | 10 440 | Threatening. |
| 9- 6-06 | 3.02-3.32 " | | 201 | 280 | 481 | 11 544 | Fair. |
| 9- 6-06 | 3.55-4.25 " | First Avenue and Thirty-fourth Street. | 342 | 110 | 452 | 10 848 | Fair. |
| 8-13-06 | 10.50-11.20 A. M. | Eighth Avenue and Forty-first Street. | 185 | 22 | 207 | 4 968 | Fair. |
| 8-13-06 | 3.50-4.20 P. M. | | 170 | 28 | 198 | 4 752 | Fair. |
| 8-14-06 | 2.53-3.23 " | | 156 | 32 | 188 | 4 512 | Fair. |
| 8-16-06 | 3.30-4.00 " | | 147 | 37 | 184 | 4 416 | Fair. |

Mr. Richardson.

TABLE 13.—TRAFFIC IN BOSTON, MASS., IN 1906.

| Date. | Street. | Number of Hours. | Collars. |
|---|---|---|---|
| 4-23-06 | Devonshire Street, Milk to Water Streets | 10 | 4 384 |
| 24 | " " " " " | 10 | 4 310 |
| 25 | Tremont Street, Scollay Square to School Street | 10 | 4 261 |
| 9-5-06 | Charles Street, Fruit and Allen Streets | 10 | 2 650 |
| 6 | Court Street, Washington Street to Court Square | 10 | 3 290 |
| 7 | Columbus Avenue, Ferdinand to Berkeley Streets | 9 | 1 440 |

In reply to the statements of Messrs. Whinery, Lewis and Tillson: Nobody can appreciate more than the writer the necessity for standardizing methods of counting traffic and stating the results. Unfortunately, nothing of this kind has been done, and, as a result, vehicles alone are counted in one city, vehicles and tons per foot run, either with or without the horses, in another city, and collars alone in another. As far as the writer has been able to learn, the subject has not been considered by any of the societies which might have done so, and it seems to be necessary that something of this sort should be done, as the data which have been collected heretofore are of much less value than if they had been obtained by following some definite system.

The writer is informed by the Chairman of the Committee on Standard Tests of Road Materials, of the American Society for Testing Materials, that, as far as he is aware, that committee has never given any consideration to, or appointed any sub-committee to consider, a standard method for observing traffic and compiling data.

Mr. Lewis presents the objection that counts covering but an hour or two may lead to erroneous deductions, but determinations made in this way in London on several occasions confirm closely the results of the count of the Royal Commission extending over periods of a week or more. Of course, judgment must be used in interpreting the results and in selecting a time when an average traffic is going on.

Mr. Lewis is mistaken in supposing that the data which have been presented in the paper were collected by two men. There were four, one observer and one man with a tally sheet, for traffic in each direction. Under these circumstances, there does not seem to be reason to believe that there are any gross errors.

The reason given by Mr. Lewis as a possible cause for the falling off in the traffic on Broadway seems to the writer to be correct.

# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

OF

# CIVIL ENGINEERS.

(INSTITUTED 1852.)

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VOL. XXXII. No. 9.

NOVEMBER, 1906.

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NEW YORK 1906.

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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Vol. XXXII. NOVEMBER, 1906. No. 9.

# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## SOCIETY AFFAIRS.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

**November 7th, 1906.**—The Society met at 8.40 P. M.; Vice-President Emil Kuichling in the chair; Charles Warren Hunt, Secretary; and present, also 124 members and 29 guests.

The minutes of the meetings of October 3d and 17th, 1906, were approved as printed in the *Proceedings* for October, 1906.

A paper by Allen Hazen, and E. D. Hardy, Members, Am. Soc. C. E., entitled, "Works for the Purification of the Water Supply of Washington, D. C.," was presented by Mr. Hardy, and illustrated with lantern slides. The Secretary read communications on

the subject from Messrs. Francis F. Longley, Theodore M. Leisen, and W. L. Butcher, and Doctors William C. Woodward, and George M. Kober, and the subject was discussed orally by Messrs. J. P. A. Maignen, William T. Sedgwick, and Charles Moore, and Dr. G. Lloyd Magruder.

The Secretary reported that a sufficient number of ballots on the appointment of a Special Committee on the Metric System had been received to enable the count to be made.

It was moved, seconded, and carried that the Secretary be directed to canvass the ballot and report the result to the Board of Direction.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Joshua Thomas Noble Anderson, Dunedin, New Zealand.
William Gerrie Brown, Portland, Ore.
Clark Robinson Fickes, Shreveport, La.
Gadsden Edwards Shand, Columbia, S. C.
John Herman Smith, Clinton, Okla.
Ira Wallace Sylvester, Alexandria, La.
Prosper Eugene Thian, Brandon, Man., Canada.
Clarence George Vaughn, New Orleans, La.
Frank Robert Williamson, Chicago, Ill.

As Associate Members.

Henry Welcome Ballou, Providence, R. I.
Arthur Henry Birks, New Liverpool, Que., Canada.
Edward Gatling Bradbury, Columbus, Ohio.
George Doswell Brooke, Cumberland, Md.
Philip Burgess, Columbus, Ohio.
Samuel Powers Connor, New York City.
William Pierce Cowles, Minneapolis, Minn.
John Stephen Doyle, Baltimore, Md.
Henry Exall Elrod, Joplin, Mo.
Elmer Wallace Firth, New York City.
Martin Welch Hall, New York City.
Herman Keene Higgins, Cristobal, Canal Zone, Panama.
Charles Anthony Ingersoll, Medina, N. Y.
Everett Edgar King, St. Louis, Mo.
Robert Lincoln Murphy, St. Louis, Mo.
Albert Lyon Scott, Boston, Mass.
Jens Kristian Selmer, City of Mexico, D. F., Mexico.
Pius Melanthon Speicher, Philadelphia, Pa.
Alexander Milton Vance, Hurley, Mo.

George Reed Wadsworth, New York City.
Arthur Burr White, Corona, Cal.
George P. Williams, Jamaica, N. Y.
John Low Zachry, Davis, Ind. T.

As Associates.

George Joseph Hurst, New York City.
Leslie Abram Waterbury, Urbana, Ill.

The Secretary announced:

The transfer of the following candidates by the Board of Direction, on October 30th, 1906:

From Associate Member to Member.

Rollo Glenroy Manning, Ambridge, Pa.
Charles Eliphalet Trout, New York City.

The election of the following candidates by the Board of Direction:

As Juniors.

On May 1st, 1906:

George Sykes, New York City.

On October 30th, 1906:

Harold William Beers, Taunton, Mass.
Carl William Birch-Nord, Chicago, Ill.
Horace Butterfield Coburn, Jr., New York City.
Harry Aten Cook, Jersey City, N. J.
John Wheeler Cook, Passaic, N. J.
Philip Dakin Gillham, St. Louis, Mo.
Augustus Griffin, Modesto, Cal.
Russell Edwin Harrison, Toledo, Ohio.
Edward John Mehren, Lo Lo, Mont.
Herman Fred Scholtz, Cochran, Va.
Clifford Bradley Suttle, Philadelphia, Pa.
Foster Towle, High Falls, N. Y.
Carl Felix Kill-Mar von Blücher, Ennis, Tex.
George Edward Willcomb, Watertown, N. Y.

The Secretary announced the death of William Tyndale Jennings, elected Member April 2d, 1884; died October 24th, 1906.

Adjourned.

**November 21st, 1906.**—The Society met at 8.40 P. M.; Vice-President Kuichling in the chair; Chas. Warren Hunt, Secretary; and present, also, 122 members and 27 guests.

A paper by Joseph Mayer, M. Am. Soc. C. E., entitled "Steam Locomotive and Electric Operation for Trunk-Line Traffic—A Comparison of Costs and Earnings," was presented by the author, and discussed by F. J. Sprague, M. Am. Soc. C. E., and the author.

The Secretary announced the following deaths:

FREEMAN CLARKE COFFIN, elected Member February 6th, 1905; died November 11th, 1906.

ELVER LA ZELLE SHINBUR, elected Associate Member October 3d, 1906; died November 7th, 1906.

EDDY ELBERT YOUNG, elected Associate Member January 6th, 1904; died June —, 1906.

ALBERT HENRY ZELLER, elected Junior May 7th, 1890; Associate Member April 7th, 1897; died November 2d, 1906.

ARTHUR PRICE LAW, elected Associate Member June 3d, 1903; died November 19th, 1906.

Adjourned.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, December 5th, 1906.**—8.30 P. M.—At this regular business meeting, ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "The Atchafalaya River: Some of Its Peculiar Physical Characteristics," by J. A. Ockerson, M. Am. Soc. C. E.; and "The Naval Floating Dock—Its Advantages, Design and Construction," by Leonard M. Cox, M. Am. Soc. C. E.

The paper by Mr. Ockerson was printed in *Proceedings* for September, 1906; Mr. Cox's paper was printed in *Proceedings* for October, 1906.

**Wednesday, December 19th, 1906.**—8.30 P. M.—A paper entitled "Recent Practice in Hydraulic-Fill Dam Construction," by James D. Schuyler, M. Am. Soc. C. E., will be presented for discussion at this meeting.

This paper is printed in *Proceedings* for October, 1906.

**Wednesday, January 2d, 1907.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "The Necaxa Plant of the Mexican Light and Power Company," by F. S. Pearson and F. O. Blackwell, Members, Am. Soc. C. E., will be presented for discussion.

This paper is printed in *Proceedings* for October, 1906.

**Wednesday, February 6th, 1907.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Lighthouse Construction in the Philippines," by Spencer Cosby, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

**Wednesday, February 20th, 1907.**—8.30 P. M.—A paper entitled "Rainfall, and Run-Off in Storm-Water Sewers," by Charles Emerson Gregory, Assoc. M. Am. Soc. C. E., will be presented for discussion at this meeting.

This paper is printed in this number of *Proceedings*.

## ANNUAL MEETING.

The Fifty-fourth Annual Meeting will be held at the Society House, on Wednesday and Thursday, January 16th and 17th, 1907. The Business Meeting will be called to order at 10 o'clock on Wednesday morning. The Annual Reports will be presented, officers for the ensuing year elected, members of the Nominating Committee appointed, proposed amendments to the Constitution presented for action, and other business transacted.

## PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 803 Fulton Building, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner, Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten-Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesbrough, England.

**Civil Engineers' Society of St. Paul,** St. Paul, Minn.

**Koninklijk Instituut van Ingenieurs,** The Hague, The Netherlands.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

## LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

### San Francisco, Cal.

(Abstract.)

**October 20th, 1906.**—A regular meeting of the San Francisco Association of Members, Am. Soc. C. E., was held; Edwin Duryea, Jr., President, in the chair; Franklin Riffle, Secretary; and present, also, 24 members and 2 guests.

The minutes of the previous meeting were read and approved.

Reports were received from the special committees on Geology of the Earthquake; and on Building Construction; also a supplementary report on the Vertical Movement of the Earthquake of April 18th, 1906, in certain sections of the Earthquake Area. The chairman of the Sewers Committee reported progress.

The chair stated that the report of the Water-Works Committee was completed.

# ACCESSIONS TO THE LIBRARY.

From October 8th to November 13th, 1906.

## DONATIONS.*

### HENLEY'S ENCYCLOPÆDIA OF PRACTICAL ENGINEERING AND ALLIED TRADES, VOL. I-II.

A Practical and Indispensable Work of Reference for the Mechanical Engineer, Designer, Draftsman, Shop Superintendent, Foreman and Machinist. Edited by Joseph G. Horner, A. M. Inst. M. E. Half Morocco, 7½ x 9 in., illus., 2 vol. New York, The Norman W. Henley Publishing Company, 1906. $6 per vol., or $25 for set of 5 vols.

These two volumes are the first, of a set of five comprising the whole work, which have been issued to date. The publication, as stated in the preface, is intended to cover the whole field of civil and mechanical engineering. The articles are treated from the standpoint of the practical engineer and the man in the shop, but it is hoped that they may prove of value, for reference, to the manufacturer and student as well. The various processes, machines and tools used in the workshop are described and freely illustrated with original working drawings, diagrams and photographs. In an endeavor to make the encyclopædia more valuable, the practice of the various trades included in engineering construction has been given special attention, and to that end the articles dealing with these subjects have been written by men who are entirely familiar with them. It has thus been the endeavor of the publishers to familiarise mechanics and others with those parts of their own work which, owing to specialisation, they have had no opportunity to study. The articles on any one subject are not long, but there are many separate articles on related subjects of importance. Cross-references have also been freely used in order to facilitate the work of those looking up any subject.

### LE CARBONE ET SON INDUSTRIE.

Par Jean Escard. Paper, 10 x 7 in., illus., 18 + 763 pp. Paris, H. Dunod et E. Pinat, 1906. 25 francs.

In this book the author has endeavored to describe as minutely as possible the recent applications of the different kinds of carbon, especially those which are of great interest and industrial importance. A general review of the properties of carbon, in the first chapter, is followed by a study of the diamond and its applications. Graphite is then taken up, and, with its applications, is described at length. Another chapter is devoted to the uncrystallized carbons, the applications and characteristics of each being discussed. The last two chapters are devoted to a study of coal. The author has endeavored not only to give a description of the mineral and its properties, but has also described its geological formation as found in France as well as in Europe and other parts of the world. He concludes with information as to the exhaustion of the coal supply and a fuel for the future. The Contents are: Propriétés Générales des Carbones; Le Diamant; Gisements Diamantifères; Applications Industrielles du Diamant; Mode de Formation du Diamant dans la Nature et Essais de Reproduction; Le Graphite et les Charbons Eléctriques; Les Carbones Amorphes: Charbon de Bois; Noirs Industriels; Coke; Charbon de Cornue; La Houille et ses Differentes Variétés; Applications Industrielles de la Houille; Description des Principaux Gisements.

### LE CANAL DE SUEZ.

Par Voisin Bey. Paper, 9 x 6 in., illus., 7 vol. and Atlas (12 x 9). H. Dunod et E. Pinat, 1902-06. 90 francs.

These volumes comprise a complete legal and financial history of the Suez Canal, as well as a history of the engineering work. The publication is divided into two parts. The first part, included in the first three volumes, covers the period from 1854, the date of the first Act of Concession, to 1902. It is a complete résumé of all the questions arising, during that period, between the Company and the Egyptian and other governments, together with all questions concerning the constitution and administration of the Company. The second part, or the last four volumes, covers the period from 1854 to 1869, the year in which

*Unless otherwise specified, books in this list have been donated by the publisher.

the Canal was opened to navigation. It includes a detailed history of the engineering work, the surveys, methods and materials used, together with a financial review of the project. The Atlas contains forty plates, illustrating various interesting features of the work. It is probable that engineers and contractors of large public works will find much that is interesting and instructive in these volumes.

**MANUAL OF EXAMINATIONS FOR ENGINEERING POSITIONS**

In the Service of the City of New York: Questions and Answers in 3 Volumes. Vol. I, Part II, Chainman and Rodman; Vol. I, Part III, Leveler; Vol. II, Part II, Assistant Engineer, General, Aqueduct, Docks, Sewers and Highways; Vol. III, Part I, Draftsman and Draftsman's Helper. Paper, 9 x 6 in., illus., 4 vol. New York, The Engineering News Publishing Company, 1906. Vol. I, Part II, 60 cents; Part III, 60 cents; Vol. II, Part II, $1.25; Vol. III, Part I, $1.00.

These books are a continuation of a work which is being issued in three volumes, each of which contains several parts. The parts already published are as follows: Vol. I, Part I, Axeman; Vol. I, Part IV, Transitman and Carpenter; and Vol. II, Part I, Assistant Engineer, Rapid Transit Commission. Each of the present volumes, like the earlier ones, contains questions given at previous examinations, followed by blank pages for the addition of new sets, and a section containing typical questions and answers with illustrations and problems. In the preface to Vol. II, Part II, "Assistant Engineer, General, Aqueduct, Docks, Sewers and Highways," it is stated that the papers marked "Miscellaneous Questions" have been compiled from many sources, being questions asked at examinations held previous to the dates given. It is hoped that they will greatly increase the value of the book. It is also stated that, in order to conform with the best modern practice, and because of variance of opinion which may exist as to what is the best answer, owing to differences in interpretation of the question and in education and experience, great care has been taken to base the answers given on the works of recognized authorities.

**RAILROAD ACCIDENTS:**

Their Cause and Prevention. By R. C. Richards. Cloth, 7 x 5 in., 111 pp. Chicago, The Association of Railway Claim Agents, 1906. 50 cents.

Mr. Richards, the author, is the General Claim Agent of the Chicago and North-Western Railway Company, in which capacity he has had greater opportunities than most men of investigating the causes and prevention of railroad accidents. The results of these investigations have been embodied in this book. The first part of the volume takes up the various causes of railroad accidents, a chapter being devoted to a general discussion of each cause. Examples of these accidents are given in almost every case, and references to operating rules, observance of which might have prevented the accident, are also given. The second part of the book contains suggestions for the prevention of such accidents. There is an Appendix containing the operating rules of railroads which are referred to in the text of the book.

**A GRAPHICAL TREATMENT OF THE INDUCTION MOTOR.**

By Alexander Heyland. Translated from the Second Edition, G. H. Rowe and R. E. Hellmund. Cloth, 8 x 6 in., illus., 48 pp. New York, McGraw Publishing Company, 1906. $1 net.

The method described in this volume consists of the practical application of the Heyland diagram for the purpose of determining the operation and commercial excellence of the induction motor. The author states that this method is based on two experimental tests on the finished motor: One with the motor running without load, and the other with stationary and short-circuited rotor. The description of the diagram and its application is preceded by a discussion on the general theory of the induction motor and the derivation of the diagram, and it is followed by practical examples of the application of the diagram, which, the author hopes, will make its use more clearly and easily understood. The Contents are: Introduction; General Theory; Diagrams of the Induction Motor; Determination of Input, etc., from the Diagram; Practical Application of the Diagram; Examples; Induction Motor as Generator; Single Phase Motor. There is no index.

**THE MANAGEMENT OF ELECTRICAL MACHINERY.**

A Thoroughly Revised and Enlarged Edition of the Practical Management of Dynamos and Motors. By Francis B. Crocker and Schuyler S. Wheeler, M. Am. Soc. C. E. Sixth Edition. Cloth, 6 x 5 in., illus., 7 + 223 pp. New York, D. Van Nostrand Company, 1906. $1 net. (Donated by S. S. Wheeler.)

The rapid progress which has been made in electrical engineering since the original edition of this book, in 1892, has made a second thorough revision of the subject-matter necessary. The object of the book, as stated by the authors, is to give simple directions for the practical use and management of generators and motors. They have confined themselves, therefore, to the management of dynamos, giving only a few of the most important definitions and structural features. References are made to works in which the theory, design and construction of the machines are given, and there are also references to elementary works on the principles of electricity, for the use of the non-electrical reader. In the present edition the original arrangement of the subject-matter has been retained, but much that is obsolete has been omitted. New and amended material has been introduced, such as the management of alternating-current generators and motors both single and polyphase, and also that of railway motors. The Contents are: Part I, Selection and Management; Part II, Inspecting and Testing; Part III, Localization and Remedy of Troubles; Part IV, Constant-Current (Arc) Generators; Part V, Management of Railway Motors. There is an index of five pages.

**THE SAN FRANCISCO EARTHQUAKE AND FIRE:**

A Brief History of the Disaster; A Presentation of Facts and Resulting Phenomena, with Special Reference to the Efficiency of Building Materials; Lessons of the Disaster. By A. L. A. Himmelwright, M. Am. Soc. C. E. Morocco, 9½ x 11 in., illus., 270 pp. New York, The Roebling Construction Company, 1906. $5.00.

This book comprises a detailed report, made by the author, to the Roebling Construction Company, as to the effects of the earthquake and fire on the various types of building construction in San Francisco. It is stated that every building of fireproof construction within the burned district was visited, and that a careful and systematic study was made of each. Detailed descriptions of a number of these buildings are given, with illustrations, followed by short discussions of the effects of the fire and earthquake on them, together with comments by the author on the features of construction which proved defective or failed to fulfil the requirements. The last chapter is devoted to a discussion of the important omissions in design which have been emphasized by the disaster in San Francisco, and which, if corrected by engineers and constructors, the author believes would serve to make future construction of this kind actually fireproof. The Contents are: Introduction; The San Francisco Earthquake and Fire; The Earthquake; The Fire; The Effects of the Fire and the Earthquake; The Non-Fire-Proof Buildings; The Fire-Proof Buildings; General Comments and Conclusions; The Lessons of the Disaster.

**THE DESIGN OF STEEL MILL BUILDINGS**

And the Calculation of Stresses in Framed Structures. By Milo S. Ketchum, Assoc. M. Am. Soc. C. E. Second Edition, Enlarged. Cloth, 9 x 6 in., illus., 14 + 464 + 16 pp. New York, The Engineering News Publishing Co., 1906. $4 net.

The first edition of this work was published in 1903. The present edition is enlarged by the addition of about 100 pages of new material, including many new cuts. In the preface to the first edition, it is stated that the work is intended to provide a short course in the calculation of stresses in framed structures, and to give a brief discussion of mill building construction. Both the algebraic and graphic methods of calculating stresses are fully described and illustrated. While the construction of mill buildings is the real object of the book, much of the subject-matter can be applied to all classes of steel frame construction. Under the subject of mill building construction, the author has given the methods of construction and the materials used, together with a brief treatment of mill building design and the making of estimates of weight and cost, especially those methods, data and details which are not ordinarily available to engineers. The additions to the present edition include a discussion of influence diagrams; the calculation of stresses in pins; a chapter on "Graphic Methods for Calculating the Deflection of Beams"; data on loads, foundations and saw-toothed roofs; descriptions of various buildings; and an appendix

giving the analyses of 22 problems in Graphic Statics. The Contents are: Introduction; Part I, Loads: Dead Loads; Snow Loads; Wind Loads; Miscellaneous Loads. Part II, Stresses: Graphic Statics; Stresses in Framed Structures; Stresses in Simple Roof Trusses; Simple Beams; Moving Loads on Beams; Stresses in Bridge Trusses; Stresses in a Transverse Bent; Stresses in Portals; Stresses in Three-Hinged Arch; Stresses in Two-Hinged Arch; Combined and Eccentric Stresses; Graphic Methods for Calculating the Deflection of Beams. Part III, Design of Mill Buildings: General Design; Framework; Corrugated Steel; Roof Coverings; Side Walls and Masonry Walls; Foundations; Floors; Windows and Skylights; Ventilators; Doors; Shop Drawings and Rules; Paints and Painting; Estimate of Weight and Cost. Part IV, Miscellaneous Structures. There are two Appendices: one containing Specifications for Steel Frame Buildings; and the other, Problems in Graphic Statics and the Calculation of Stresses. There is also an index of six pages, followed by tables of structural details.

**THE PRINCIPLES AND PRACTICE OF SURVEYING.**

By Charles B. Breed, Assoc. M. Am. Soc. C. E., and George L. Hosmer. Cloth, 9 x 6 in., illus., 18 + 526 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1906. $3.00. (Donated by the Authors.)

It is stated in the preface that this book is essentially an elementary treatise on the subject, the authors' chief purpose having been to produce a textbook which shall include the essentials of a knowledge of practical surveying and, at the same time, be adapted to the use of teachers and students of technical schools. For these reasons, such subjects as stadia, plane table, hydrographic and geodetic surveying have been omitted. The subject-matter of the work has been divided into four parts, in order to present the process of surveying to the student as it is met in the daily practice of the surveyor; and to make the steps in the process more clear, the notes which are used as illustrations in surveying methods are calculated in the computation section and treated again under the methods of plotting, appearing finally as a completed plan. A comprehensive cross-reference system has been used, which, together with the many practical suggestions given throughout the volume, will, it is hoped, make the book useful as a reference book to the practical surveyor. The Contents are: Part I, Use, Adjustment and Care of Instruments: General Definitions, Measurement of Lines; Measurement of Direction; Measurement of Angles; Measurement of Differences of Elevation. Part II, Surveying Methods: Land Surveying; Traverse Lines, Location of Buildings; Miscellaneous Surveying Problems; Observations for Meridians and Latitude; Leveling; City Surveying; Topographical Surveying; Mining Surveying. Part III, Computations: General Principles, Miscellaneous Problems, Earthwork Calculations; Area by Double Meridian Distances, Coördinates. Part IV, Plotting: Drafting Instruments and Materials; Methods of Plotting; Finishing and Filing Drawings; Tables. There is an index of nine pages, and the book is illustrated with original drawings.

**PROBLEMS IN SURVEYING, RAILROAD SURVEYING AND GEODESY.**

With an Appendix on the Adjustments of the Engineer's Transit and Level. By Howard Chapin Ives, Jun. Am. Soc. C. E. and Harold Ezra Hilts. Morocco, 7 x 4 in., illus., 9 + 136 pp. New York, John Wiley & Sons, 1906. $1.50.

The problems given in this book have been used by the authors' classes in civil engineering at the University of Pennsylvania for the past three years. They are now issued in book form, with the hope that they may prove of service to similar classes at other institutions as a manual covering the field courses. As indicated by the title, the subject-matter includes problems which may be used in courses of plane surveying, railroad surveying, and geodetic and topographic surveying. It is stated that it has been the aim of the authors to make the work as practical as possible, sufficient theory being given for a reasonable understanding of the problems. Specimen notes are given in many cases; where they are not given, the requirements are stated, so that the required form of report is plainly shown. The Contents are: General Directions for Field-Books; Chaining Problems; Leveling Problems; Compass Problems; Transit Problems; Miscellaneous Field and Office Problems; Railroad Surveying Problems; Geodetic Problems; Astronomical Problems; Surveys. There is an appendix containing a chapter on "The Adjustments of the Engineer's Transit and Level," followed by several tables of elevations, etc.

**BATTER TABLES**

For 192 Batters from $\frac{1}{16}$-In., $\frac{1}{8}$-In., $\frac{3}{16}$-In. to 12 Inches per Foot; Giving Altitude and Hypothenuse in Feet and Decimals of

Feet for Any Base Measured in Feet, Inches and Sixteenths; with a Table of Equivalents of Inches and Fractions in Decimals of a Foot. By C. G. Wrentmore, Assoc. M. Am. Soc. C. E. Cloth, 10 x 8¼ in., unpaged. New York, Engineering News Publishing Company, 1906. $5.00 net.

In presenting these tables in book form, the author hopes that they will justify the work of preparation by lightening the labor and increasing the accuracy and reliability of drafting-room work. They are not intended to replace tables of squares and logarithms, but rather to supplement them, and it is believed that they will prove more economical of time and labor, and, at the same time, lessen the chances of error. Great care has been taken in preparing them to eliminate all errors by systematizing the computation and by repeated checking.

**ECONOMICS OF ROAD CONSTRUCTION.**

By Halbert Powers Gillette, M. Am. Soc. C. E. Second Edition, Enlarged. Cloth, 9 x 6 in., illus., 49 pp. New York, The Engineering News Publishing Co., 1906. $1.00.

The Contents are: I, Historical Review. II, Earth Roads and Earthwork: Profile of Cross-Section of Road; Longitudinal Profile; Gutters and Drains; Embankments; Cost of Earthwork; Surfacing; Traction and Tractive Power; Location. III, Gravel Roads. IV, Macadam Roads: What Holds Macadam Together; Quality of Stone; Relative Wearing Powers of Stone; Quarrying; Dynamite; Crushing; Hauling; Spreading; Rolling; Sprinkling; Quantity and Cost. V, Telford Roads. VI, Repairs and Maintenance: Continuous *vs.* Intermittent System; Sandstone Macadam. VII, Suggested Improvements in Existing Road Specifications: Kind and Sizes of Broken Stone; Depth of Pavement; Final Surfacing; Material for Embankments; Thickness and Width of Pavement. VIII, Summary and Conclusions. There is no index.

**THE UNIVERSAL DIRECTORY OF RAILWAY OFFICIALS, 1906.**

Compiled from Official Sources Under the Direction of S. Richardson Blundstone. Cloth, 9 x 6 in., 579 pp. London, The Directory Publishing Company, Limited; New York, A. Fenton Walker, 143 Liberty St., 1906. Seven shillings six pence.

The contents of this book, it is stated, have been compiled entirely from official sources. This edition, the twelfth, has been carefully revised and brought up to date, with several additions. Names of railways in all parts of the world, arranged alphabetically under countries, are given, together with the names and addresses of all the officials connected with them. Practically all tramways worked by power in the United Kingdom are also given. The length of each railway immediately follows the name, either in English miles or kilometers; the gauge is given in feet and inches, or in meters. The amount of rolling stock owned by each railway is also included. At the end of the book is an alphabetical index of manufacturers and suppliers of railway plants and material, machinery, stores and appliances, arranged by subject. There are also alphabetical indices of countries, names of railways, and a personal index of railway officials.

Gifts have also been received from the following:

Am. Electrochemical Soc. 1 bound vol.
Am. Forestry Assoc. 7 pam.
Am. Ry. Master Mechanics' Assoc. 1 bound vol.
Assoc. of Am. Portland Cement Mfrs. 1 pam.
Assoc. of Executive Health Officers of Ontario. 12 pam.
Atchison, Topeka & Santa Fe Ry. Co. 1 pam.
Bangor & Aroostook R. R. Co. 1 pam.
Berg, W. G. 36 vol.
Bey, Voisin. 4 vol.
Bituminous Coal Trade Assoc. 1 pam.
Boston, Mass.—Board of Park Commrs. 1 pam.
Boston, Mass.—Public Library. 1 vol.
British Fire Prevention Committee. 3 bound vol.
Canada—Geol. Survey. 1 bound vol., 21 maps.
Canadian Pacific Ry. Co. 3 pam.
Canadian Soc. of Civ. Engrs. 1 pam.
Central Vermont Ry. Co. 1 pam.
Chesapeake & Ohio Ry. Co. 3 pam.
Chicago, Ill.—Mayor. 1 bound vol.
Chicago, Burlington & Quincy R. R. Co. 2 pam.
Collegio degli Ingegneri e Architetti in Palermo. 1 pam.
Colorado & Southern Ry. Co. 1 pam.
Cripple Creek Central Ry. Co. 1 pam.

Detroit, Mich.—Board of Water Commrs. 2 pam.
Douglas, James. 1 pam.
Eng. Soc. of the School of Practical Sci., Univ. of Toronto. 1 vol.
Engrs. Club of New York. 1 bound vol.
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Engrs. Soc. of Western Pennsylvania. 2 pam.
Erie R. R. Co. 1 pam.
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Fuller, F. L. 3 pam.
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Hatt, W. K. 1 pam.
Idaho—State Auditor. 1 map.
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Jacksonville, Fla.—Board of Trustees for the Waterworks and Impvt. Bonds. 1 pam.
Japan—Imperial Earthquake Investigation Committee. 1 pam.
Kentucky—State R. R. Comm. 1 map.
Louisiana—R. R. Comm. 1 map.
Louisville & Nashville R. R. Co. 1 pam.
McKeesport, Pa.—Board of Water and Lighting Commrs. 1 pam.
Maine—State Board of R. R. Commrs. 1 map.
Manchester Assoc. of Engrs. 1 bound vol.
Manchester Steam Users' Assoc. 14 pam.
Maryland—State Tax Commr. 1 map.
Mass.—State Board of Health. 1 bound vol.
Mexican Inter. R. R. Co. 1 pam.
Min. Inst. of Scotland. 1 pam.
Minnesota—R. R. and Warehouse Comm. 1 map.
Mississippi—R. R. Comm. 3 maps.
Missouri Pacific Ry. Co. 1 pam.
Municipal Engrs. of the City of New York. 1 bound vol.
National Board of Fire Underwriters—Elec. Bureau. 1 pam.
New England Assoc. of Gas Engrs. 1 bound vol.
New Jersey—Geol. Survey. 1 bound vol.
New Jersey—Road Commr. 1 map.
New Jersey San. Assoc. 2 pam.
New South Wales—Board of Inter. Exchanges. 6 bound vol., 5 vol., 1 pam.
New South Wales—Govt. Statistician. 1 pam.
New York—State Board of R. R. Commrs. 2 maps.
*New York City Record.* 4 bound vol.
New York, New Haven & Hartford R. R. Co. 1 pam.
Norfolk, Va.—Board of Water Commrs. 2 pam.
Norfolk & Western Ry. Co. 1 pam.
North Carolina—Corporation Comm. 1 map.
North Dakota—State Commrs. of R. R. 1 map.
North-East Coast Inst. of Engrs. and Shipbuilders. 1 bound vol.
North of England Inst. of Min. and Mech. Engrs. 1 pam.
Northern Pacific Ry. Co. 1 pam.
Ohio—State Commr. of R. R. and Telegraphs. 1 map.
Ontario, Canada—Provincial Board of Health. 1 pam.
Ontario, Canada—Registrar-General. 1 vol.
Parsons, W. B. 1 bound vol.
Pennsylvania—Dept. of Internal Affairs. 1 map.
Permanent Inter. Assoc. of Navigation Congresses. 1 pam.
Philadelphia, Pa.—Bureau of Water. 1 pam.
Platt, T. C. 1 bound vol., 4 pam.
Queensland—Commr. for Railways. 1 pam.
St. Francis Levee Board of Arkansas. 2 pam.
St. Louis & San Francisco R. R. Co. 1 pam.
St. Louis Southwestern Ry. Co. 1 pam.
Somerville, Mass.—City Clerk. 1 pam.
South Australia-Railways Commr. 1 pam.
South Dakota—R. R. Commrs. 7 maps.
Street Ry. Assoc. of the State of New York. 3 bound vol., 3 vol.
Thompson, R. A. 1 pam.
Transvaal—Rand Water Board. 1 pam.
United Provinces of Agra and Oudh, India—Public Works Dept. 1 pam.
U. S. Bureau of Statistics. 1 pam.
U. S. Engr. School. 1 pam.
U. S. Geol. Survey. 55 maps.
U. S. Lake Survey Office. 3 maps, 1 pam.
U. S. Naval Observatory. 2 bound vol.
U. S. Naval War Records Office and Library. 1 vol., 1 pam.
U. S. War Dept. 15 specif.
Univ. of Illinois—Agri. Exper. Station. 3 pam.
Vermont—State Board of R. R. Commrs. 1 map.
Wabash R. R. Co. 1 pam.
West Virginia—State Geologist. 1 map.
Western Australia—Geol. Survey. 2 vol.
Wilgus, W. J. 1 pam.
Wisconsin—R. R. Comm. 1 map.

## BY PURCHASE.

**The Mineral Industry,** its Statistics, Technology and Trade during 1905. Vol. 14. Edited by Walter Renton Ingalls. New York and London, Engineering and Mining Journal (Incorporated), 1906.

**Charles Eliot, Landscape Architect.** Boston and New York. Houghton, Mifflin & Company, 1903.

**Manual of Wireless Telegraphy.** By A. Frederick Collins. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1906.

**Outlines of Practical Sanitation** for Students, Physicians and Sanitarians. By Harvey B. Bashore. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1906.

**Beton-Kalender,** 1907; Taschenbuch für Beton- u. Eisenbetonbau, sowie die verwandten Fächer. Unter Mitwirkung hervorragender Fachmänner herausgegeben von der Zeitschrift *Beton u. Eisen.* Pts. 1–2. Berlin, Wilhelm Ernst & Sohn, 1906.

**Etude Experimentale du Ciment Arme.** Par R. Feret. Paris, Gauthier-Villars, 1906.

**Steam Turbine Engineering.** By T. Stevens and H. M. Hobart. New York, The Macmillan Co.; London, Whittaker & Company, 1906.

**A Conspectus of American Biography.** Compiled by George Derby. New York, James T. White & Company, 1906.

**Moody's Manual of Railroads and Corporation Securities.** Seventh Annual Number, 1906. New York, Chicago, The Moody Corporation; London, Fredc. C. Mathieson & Sons; Amsterdam, Holland, J. H. De Bussy, 1906.

**Illinois State Geological Survey.** Bulletin No. 1. The Geological Map of Illinois. By Stuart Weller. Urbana, Ill., University of Illinois, 1906.

**U. S. Geological Survey.** Topographic Sheets. 36 Maps. Washington, D. C., U. S. Geological Survey, 1895–1906.

## SUMMARY OF ACCESSIONS.

From October 8th to November 13th, 1906.

| | |
|---|---|
| Donations (including 81 duplicates) | 372 |
| By purchase | 47 |
| Total | 419 |

## MEMBERSHIP.

### ADDITIONS.

| MEMBERS. | | Date of Membership. |
|---|---|---|
| ASH, HENRY CLARKE. Thomson, Minn | | Oct. 3, 1906 |
| BISHOP, WILLIAM ISRAEL. Eng. Contr., 134 Mackay St., Montreal, Que., Canada | Assoc. M. | Feb. 6, 1901 |
| | M. | Oct. 2, 1906 |
| BOECKLIN, WERNER. Civ. and Mech. Engr., 56 Pine St., New York City | Jun. | Mar. 1, 1892 |
| | Assoc. M. | Dec. 1, 1897 |
| | M. | Dec. 5, 1905 |
| CALLAGHAN, JOHN. Div. Engr., Constr. Dept., Canadian Pacific Ry. Co., Winnipeg, Man., Canada | | Oct. 3, 1906 |
| DANFORTH, RICHARD EUGENE. 267 State St., Rochester, N. Y. | | Oct. 3, 1906 |
| GUTELIUS, FREDERICK PASSMORE. Asst. Chf. Engr., Canadian Pacific Ry., Montreal, Que., Canada | | Oct. 3, 1906 |
| HALLOCK, JAMES CURRIE. 200 West 95th St., New York City | | Oct. 3, 1906 |
| KUMMER, FREDERIC ARNOLD. Chf. Engr., United States Wood Preserving Co., 29 Broadway, New York City | Jun. | April 30, 1895 |
| | Assoc. M. | Mar. 4, 1903 |
| | M. | Oct. 2, 1906 |
| LEIGHTON, GEORGE. Res. Engr. on Tunnel Constr., Penn., N. Y. & L. I. R. R. Co., 345 East 33d St., New York City | | Oct. 3, 1906 |
| LLEWELLYN, FREDERICK THOMAS. Care, Carnegie Steel Co., 71 Broadway, New York City | Assoc. M. | Oct. 4, 1899 |
| | M. | May 1, 1906 |
| MANNING, ROLLO GLENROY. Engr., Ambridge Plant, Am. Bridge Co., Ambridge, Pa. | Assoc. M. | Oct. 2, 1901 |
| | M. | Oct. 30, 1906 |
| MARSH, CHARLES FLEMING. Engr.'s Dept., Met. Water Board, Savoy Court, London, England | | Oct. 3, 1906 |
| MORTON, WALTER SCOTT. 36 Pearl St., Hartford, Conn. | | Oct. 3, 1906 |
| ROMMEL, GEORGE, JR. Pensacola, Fla. | Jun. | Jan. 3, 1899 |
| | Assoc. M. | Mar. 5, 1902 |
| | M. | Oct. 2, 1906 |
| SPRAGUE, ERNEST MARSHALL. 1310 Rockefeller Bldg., Cleveland, Ohio | | Oct. 3, 1906 |
| SUTTON, FRANK. Topographer, U. S. Geological Survey, Washington, D. C. | | Oct. 3, 1906 |
| TROUT, CHARLES ELIPHALET. Asst. Engr., Dept. of Docks and Ferries, Pier A, North River, New York City | Jun. | Oct. 31, 1899 |
| | Assoc. M. | Jan. 8, 1902 |
| | M. | Oct. 30, 1906 |
| VAN NORDEN, ERNEST MAITLAND. Civ. Engr., New York Edison Co., 55 Duane St., New York City | Assoc. M. | May 6, 1903 |
| | M. | Oct. 2, 1906 |
| WICKES, EDWARD DANA. P. O. Box 458, Ambridge, Pa. | Assoc. M. | Dec. 3, 1902 |
| | M. | Oct. 2, 1906 |

ASSOCIATE MEMBERS.

| | Date of Membership. |
|---|---|
| BRADBURY, EDWARD GATLING. Cons. San. Engr., 85 North High St., Columbus, Ohio | Nov. 7, 1906 |
| BROOKE, GEORGE DOSWELL. Asst. Engr., B. & O. R. R., P. O. Box 225, Cumberland, Md. | Nov. 7, 1906 |
| BURGESS, PHILIP. Special Asst. Engr., Ohio State Board of Health, Columbus, Ohio | Nov. 7, 1906 |
| CONRAD, LOWELL EDWIN. 722 Cherokee St., South Bethlehem, Pa. | Oct. 3, 1906 |
| COOKE, FREDERICK HOSMER. Asst. Civ. Engr., U. S. N., Naval Station, Cavite, Philippine Islands | July 9, 1906 |
| COREY, RAY HOWARD. Civ. Engr., Utah Light & Ry. Co., Salt Lake City, Utah | Oct. 3, 1906 |
| FREY, FRANK EDWARD. Hammon, Yuba Co., Cal. | Oct. 3, 1906 |
| HALL, MARTIN WELCH. Bureau of Sewers, Borough of the Bronx, New York City... | Jun. Oct. 1, 1901<br>Assoc. M. Nov. 7, 1906 |
| HAYT, ROBERT OLCOTT. Asst. Engr., U. S. Geological Survey, Reclamation Service, Huntley, Mont. | Oct. 3, 1906 |
| HEWITT, GEORGE. 234 Fifth Ave., New York City | Oct. 3, 1906 |
| HOLT, LESTER MORTON. Asst. Engr., U. S. Reclamation Service, Hazen, Nev | Oct. 3, 1906 |
| LAWSON, LAWRENCE MILTON. Asst. Engr., U. S. Reclamation Service, Yuma, Ariz. | Oct. 3, 1906 |
| LETSON, THOMAS HERBERT. 39 Cortlandt St., New York City | Assoc. Mar. 1, 1905<br>Assoc. M. Oct. 2, 1906 |
| MACLAY, EDGAR GLEIM. 7117 Yale Ave., Chicago, Ill. | Oct. 3, 1906 |
| MURPHY, ROBERT LINCOLN. Contr. Engr., Expanded Metal & Corrugated Bar Co., 925 Frisco Bldg., St. Louis, Mo | Nov. 7, 1906 |
| MYERS, WILLIAM MADISON. Care, The Mexican Light & Power Co., San Jose el Real 22, Mexico, D. F., Mexico | Oct. 3, 1906 |
| PRICE, PAUL LEON. 427 Roxboro Ave., Philadelphia, Pa. | Oct. 3, 1906 |
| RANNELLS, CLARENCE J. 1411 Murdock Ave., Parkersburg, W. Va. | Oct. 3, 1906 |
| SHEDD, GEORGE GARNETT. 62 Barnaby St., Fall River, Mass. | Oct. 3, 1906 |
| SHINBUR, ELVER LA ZELLE. Engr., U. S. Reclamation Service, Mitchell, Nebr. | Oct. 3, 1906 |
| STENGEL, CARL HENRY. Designing Engr., Tidewater Ry., Norfolk, Va. | Oct. 3, 1906 |
| TRACY, LOUIS DOWNER. 47 Mansion Ave., Allegheny, Pa. | Oct. 3, 1906 |
| WELLS, GEORGE MILLER. Div. Engr. Office, Cristobal, Canal Zone, Panama | Oct. 3, 1906 |

ASSOCIATES.

| | |
|---|---|
| MCINTIRE, THOMAS BURTON. 2865 Briggs Ave., Bronx, New York City | Jun. Mar. 1, 1904<br>Assoc. Oct. 3, 1906 |

JUNIORS.

| | Date of Membership. |
|---|---|
| BIRCH-NORD, CARL WILLIAM. 1247 Monadnock Blk., Chicago, Ill. | Oct. 30, 1906 |
| CHEVALIER, LOUIS. 906 Porter St., Detroit, Mich. | May 1, 1906 |
| COBURN, HORACE BUTTERFIELD, JR. 19 East 41st St., New York City | Oct. 30, 1906 |
| COOK, HARRY ATEN. 132 Fairview Ave., Jersey City, N. J. | Oct. 30, 1906 |
| GILLHAM, PHILIP DAKIN. 925 Frisco Bldg., St. Louis, Mo. | Oct. 30, 1906 |
| HYDE, EDWARD WYLLYS, JR. 7117 Yale Ave., Chicago, Ill. | Sept. 4, 1906 |
| MCCLINTOCK, JAMES ROBINSON. Care, Hering & Fuller, 170 Broadway, New York City | Oct. 2, 1906 |
| MENDENHALL, HERBERT DRUMMOND. Care, U. S. Engr. Dept., Tampa, Fla | Sept. 4, 1906 |
| PENDLEBURY, EDWARD. 45 South 13th St., Newark, N. J. | Oct. 2, 1906 |
| ROMMEL, WILLIAM GUSTAVE. P. O. Box 762, Pensacola, Fla | Oct. 2, 1906 |
| SAWYER, WALTER PERCY. 4243 Calumet Ave., Chicago, Ill | Sept. 4, 1906 |
| SCHOLTZ, HERMAN FRED. Cochran, Va. | Oct. 30, 1906 |
| STANTON, WILBOR DICKENS. Dept. of Eng., Las Cascadas, Canal Zone, Panama. | Oct. 2, 1906 |

## RESIGNATIONS.

MEMBERS.

| | Date of Resignation. |
|---|---|
| BRADLEY, WILLIAM HAMMATT. | Oct. 30, 1906 |

JUNIORS.

| | |
|---|---|
| NUTTER, CHARLES HERBERT. | Dec. 31, 1905 |

## DEATHS.

COFFIN, FREEMAN CLARKE. Elected Member, February 6th, 1895; died November 11th, 1906.

JENNINGS, WILLIAM TYNDALE. Elected Member, April 2d, 1884; died October 24th, 1906.

MURAKAMI, KYOICHI. Elected Member, September 4th, 1901; died August 18th, 1906.

SHINBUR, ELVER LA ZELLE. Elected Associate Member, October 3d, 1906; died November 7th, 1906.

ZELLER, ALBERT HENRY. Elected Junior, May 7th, 1890; Associate Member, April 7th, 1897; died November 2d, 1906.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(October 8th to November 10th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles, references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month, 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeischrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.

## LIST OF ARTICLES.

### Bridge.

Ferro-Concrete Bridge Approach and Road Viaduct at Waterford; Great Southern and Western Railway, Ireland.* (21) Oct.
Interlocking of the New Barrow & Suir Opening Bridges; Great Southern & Western R., Ireland.* (21) Oct.
Ardwick-Hyde Junction Widening; Great Central R. (21) Oct.
Reconstructing the Piers of a Double-Track Railroad Bridge.* (14) Oct. 6.
The Transporter Bridge at Newport, England.* (13) Oct. 11.
A Steel Viaduct with Concrete Casing and Floor.* (13) Oct. 11.
Elevation of a Four-Track Railroad Bridge.* (14) Oct. 13.
Double-Track and Four-Track Concrete Bridges on the Philadelphia & Reading R. R. Lines.* (14) Oct. 13.
New Swing Bridge at Velsen.* (12) Oct. 19.
Concrete Viaducts on the Key West Extension of the Florida East Coast Ry.* George P. Carver. (14) Oct. 20.
Progress on the Erection of the Blackwell's Island Bridge, New York.* (14) Nov. 3.
The New Flushing Bascule Bridge.* (14) Nov. 10.
Pont Tournant sur le Canal de la Mer du Nord à Velsen (Hollande).* (33) Sept. 1.
Nouveau Pont en Maçonnerie, sur le Loire à Orléans.* (33) Sept. 29.
Système de Ponts Flottants Fixe. (33) Sept. 29.
Die Neue Schwanentorbrücke in Duisburg.* Hans Meiners. (49) Vol. 10-12, 1906.
Gitterträgerbrücken System Visintini.* F. v. E. (78) Sept.
Die Marchbrücke in Ungarisch-Hradisch.* Alfred Hawranek. (53) Serial beginning Sept. 28.
Fachwerkträger aus Eisenbeton.* S. Zipkes. (78) Serial beginning Oct.
Fortschritte im Bau Weitgespannter, Flacher, Massiver Brücken.* Leibbrand. (78) Serial beginning Oct.
Die Dimensionierung von Platten und Plattenbalken. Felix Adutt. (53) Oct. 5.
Ausführung einer Eisenbeton-Bogenbrücke mit Hilfe von Eisenbeton-Lehren.* (51) Oct. 10.

### Electrical.

Oscillographic Researches on Surging in High Tension Lines.* C. David. (Abstract with Introduction by L. A. Herdt.) (5) Dec., 1905.
The Efficiency of Lamp Globes.* J. S. Westerdale and F. C. Prentice. (Abstract.) (77) Sept.
Economic Considerations in the Employment of Storage Batteries. J. R. Salter. (77) Sept.

*Illustrated.

**Electrical—(Continued).**

The Testing of Transformers and Transformer Iron.* D. K. Morris and G. A. Lister. (77) Sept.
A Simple Method of Measuring Sparking Voltages.* E. A. Watson. (77) Sept.
Steam Turbine Dynamos.* A. G. Ellis. (77) Sept.
The Sources of Error in the Harcourt 10-CP. Pentane Standard.* J. S. Dow. (26) Sept. 28.
A New Method of Employing Twin Lead-Covered Wire for Electric Light Wiring.* E. L. Berry. (Abstract of paper read before the Elec. Contractors' Assoc.) (73) Sept. 28.
The Mercury Arc: Its Properties and Technical Applications.* E. Weintraub. (3) Oct.
The Value and Design of Water Power Plants as Influenced by Load Factor. Frederic A. C. Perrine. (3) Oct.
The Current Transformer.* Kenneth L. Curtis. (42) Oct.
The Audion; a New Receiver for Wireless Telegraphy.* Lee de Forest. (42) Oct.
Electricity in Gas-Works.* Chas. F. Botley, Assoc. M. Inst. C. E. (66) Serial beginning Oct. 9.
New Electricity Works, Birmingham.* (12) Oct. 12; (14) Oct. 27; (26) Serial beginning Oct. 12; (73) Serial beginning Oct. 12.
Calculation of the Characteristic Curves of Single-Phase Series Commutator Motors.* O. S. Bragstad and Stanley P. Smith. (73) Serial beginning Oct. 12.
Some Observations on Alternating-Current Rectifiers.* A. C. Jolley (73) Oct. 12.
The Decker Primary Battery.* Francis B. Crocker. (Paper read before the Amer. Electro-chemical Soc.) (19) Oct. 13; (27) Oct. 13.
Brush Contact Resistance.* E. Arnold. (Abstract from *Elektrotechnik und Maschinenbau.*) (73) Oct. 19.
Electric Lighting by Wind Power. E. Lancaster Burne, A. M. I. C. E. (26) Oct. 19.
Some Fundamental Characteristics of Mercury Vapor Apparatus. Percy H. Thomas. (19) Serial beginning Oct. 20.
The New Power Supply for the City of Lyons, France.* C. T. Wilkinson. (27) Oct. 20.
The Power House of the Ontario Power Co. at Niagara. V. G. Converse. (Abstract from the *Canadian Electrical News.*) (73) Oct. 26.
The Use of the Secohmmeter for the Measurement of Combined Resistances and Capacities.* S. R. Milner. (Abstract from the *Philosophical Magazine.*) (73) Oct. 26.
A Direct Method of Compensating the Armature Reaction of Alternators.* A. Heyland. (73) Oct. 26.
Distribution of Illumination in the Neighborhood of a Row of Lamps.* J. R. Benton. (27) Oct. 27.
Boffalora-Ticino Hydro-Electric Power Plant.* Alfred Gradenwitz. (46) Oct. 27.
The Necaxa-El Oro Power Plant.* Frank C. Perkins. (45) Nov.
A Modern Swiss Hydro-Electric Power Station.* Enrico Bignami. (9) Nov.
The Sale of Electric Power.* S. B. Storer. (Abstract of paper read before the N. Y. St. Ry. Assoc.) (14) Nov. 3.
The Grand Rapids-Muskegon 66 000-Volt Transmission System.* (27) Nov. 3.
Power Plant of the Waltham Gas Light Company at Waltham, Mass.* (27) Nov. 3.
Constant Direct-Current Dynamos.* E. Rosenberg. (27) Nov. 10.

**Marine.**

Development of the Marine Steam Turbine.* C. A. Parsons and R. J. Walker. (Abstract of paper read before the Inst. of Marine Engrs.) (11) Oct. 5; (47) Oct. 13.
Trials of H. M. S. *Dreadnought.* (12) Oct. 12.
Pumping Plant for the New Graving Dock at Quarry Bay, Hongkong.* (12) Oct. 12.
Marine Evaporators.* John Neill. (Paper read before the North-East Coast Inst. of Engrs. and Shipbuilders.) (47) Oct. 13.
Protection of Ships Against Torpedoes and Mines.* (12) Oct. 19.
The Iona Naval Magazine.* Walter L. Beasley. (46) Serial beginning Nov. 3.
Le Bassin d'Expériences de la Marine Française, à Paris.* L. Piaud. (33) Sept. 8.
La Drague Porteuse à Succion *Coronation.** (33) Oct. 13.
Schmiervorrichtungen für Schiffsmaschinen.* C. Strebel. (48) Serial beginning Oct. 20.

**Mechanical.**

The Wharf Cranes of the Pennsylvania Railroad Company at Greenville, N. J.* John Lyle Harrington, M. Can. Soc. C. E. (5) Dec., 1905.

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*Illustrated.

**Mechanical—(Continued).**

Memorandum for the Gas-Engine Research Committee: Method of Determining the Temperature and the Rate of Heat-Production in the Cylinder of a Gas-Engine.* H. Riall Sankey. (75) May.
Lifts and Hoists. H. C. Crews. (77) Sept.
Messrs. Richardsons, Westgarth and Co.'s Steam Turbine Department.* (26) Sept. 28.
Superheated Steam in the Power Station. Arthur S. Mann. (3) Oct.
Development of the Theory for the Kinetic Energy of Gases. Gustaf M. Westman. (3) Serial beginning Oct.
Some Characteristics of Coal as Affecting Performance with Steam Boilers.* W. L. Abbott. (4) Oct.
High Pressure Steam Tests of an Injector.* Strickland L. Kneass. (3) Oct.
A Plea for Lower Blast Pressures in Cupola and Air Furnaces.* William H. Coleman. (Abstract of paper read before the Amer. Foundrymen's Assoc.) (22) Oct. 5.
The Burning of Washer Slate and Coke Braize.* C. G. Atwater. (27) Oct. 6.
Continuous Beams or Shafts Having Three Supports.* E. Wagner. (13) Oct. 11.
Electricity in Steel Works.* (22) Oct. 12; (26) Oct. 12; (73) Oct. 12.
Air Compressing Plants for the North River Tunnels of the Pennsylvania R. R. Frank Richards. (14) Oct. 13.
Notes on the Design of a Recording Calorimeter with Data Obtained from its Use.* F. L. Cross. (Paper read before the Mich. Gas Assoc.) (24) Oct. 15; (83) Oct. 15
Coal and Coke Handling Plants.* W. Angus. (Paper read before the Midland Junior Gas Assoc.) (66) Oct. 16; (22) Oct. 19.
Scrubbing of Coal Gas. J. M'Leod. (Paper read before the Scottish Junior Gas Assoc.) (66) Oct. 16.
The New Works of the Edinburgh and Leith Gas Commissioners.* (66) Oct. 16.
The Compound-Reaction Steam-Turbine.* (11) Serial beginning Oct. 19.
The Industrial Power Problem. W. B. Esson. (Paper read before the Civil and Mech. Engrs. Soc.) (57) Oct. 19; (26) Oct. 12; (73) Oct. 12.
Relative Economy of Turbines and Engines at Varying Percentages of Rating.* Walter Goodenough. (17) Oct. 20.
Mechanical Equipment of the Carnegie Library Building Extension, Pittsburg, Pa.* (14) Serial beginning Oct. 20.
Interesting Application of Motors to Existing Machine Tools.* (27) Oct. 20.
Equipment of Modern Bridge and Structural Plants.* G. P. Thomas. (62) Oct. 20.
Flow of Air in Nozzles.* Frank Foster. (47) Serial beginning Oct. 27.
Kent's Draught Gauge.* (47) Oct. 27.
Brief Notes on High Pressure.* G. I. Vincent. (Paper read before the Iowa Gas Assoc.) (24) Oct. 29; (83) Nov.
Gas-Works Residual Products.* Samuel Glover. (Paper read before the Midland Assoc. of Gas Managers.) (66) Oct. 30.
The Clock Synchronizing Apparatus at the Leamington Priors Gas-Works. Thomas Berridge. (Paper read before the Midland Assoc. of Gas Engrs.) (66) Oct. 30.
The Realm of the Fan Blower.* Walter B. Snow. (10) Nov.
Modern Equipment and Management of a Water-Pipe Foundry.* (9) Nov.
Gas Blowing Engines.* (41) Nov.
A Study of the Inertia Fly-Wheel Governor.* H. A. Swanton. (64) Nov.
Adjusting the Rites Inertia Governor.* R. E. Cahill and S. H. Bunnell. (64) Nov.
The Bethlehem Steel Company's Recent Extension.* (20) Nov. 1.
A Novel Snow Locomotive.* (40) Nov. 2.
The Burning of Cheap Fuel.* (2?) Nov. 3.
Selection of a Steam Engine. Chas. L. Hubbard. (27) Nov. 3.
Some Economies in High Pressure Gas Transmission.* E. A. Rix. (Paper read before the Pacific Coast Gas Assoc.) (24) Nov. 5.
A Modern Car Wheel Casting Plant.* (20) Nov. 8.
De l'Influence des Masses en Mouvement dans la Machine à Vapeur.* A. Bauermeister. (37) Aug.
Note sur Quelques Jauges et Calibres.* G. Richard. (37) Aug.
Quelques Graisseurs Nouveaux.* Breuil. (Abstract from *Bulletin du Laboratoire d'Essais du Conservatoire des Arts et Métiers.*) (37) Aug.
Influence de la Vapeur à Haute Surchauffe sur le Graissage et la Déformation des Distributions.* A. Bauermeister. (37) Sept. 30.
Influence de l'Action de Paroi sur le Rendement des Moteurs à Gaz. L. Letombe. (Paper read before Le Congrès de Mécanique de l'Exposition de Liège.) (37) Sept. 30.
Les Turbines à Vapeur.* (37) Sept. 30.
Foyers à Chargement Automatique pour Chaudières à Vapeur.* (34) Oct.
Foyers Mécanique des Usines Electriques de Bercy (Paris) et de Vitry (Seine).* J. A. Lencauchez. (33) Oct. 27.
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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## LIGHTHOUSE CONSTRUCTION IN THE PHILIPPINES.

By Spencer Cosby, M. Am. Soc. C. E.

To be Presented February 6th, 1907.

In a country like the Philippines, made up of many hundreds of islands separated from one another by deep and wide arms of the sea, and provided by Nature with numerous good harbors, the water routes are, and must continue to be, the main highways of trade and travel. To them as trunk lines the roads and railroads serve as necessary feeders, and are generally built with a view to providing the shortest and cheapest means of reaching the nearest good harbor. This access to a port is the commercial question of first importance in a country whose home market for its chief products is small, and whose prosperity and very existence as a civilized land depend upon its trade with nations overseas.

The importance of the navigation interests and the need of fostering them by improving the water routes and their terminals were early recognized by the American government of the Philippines. One of its first formal acts was to provide for the prompt comple-

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

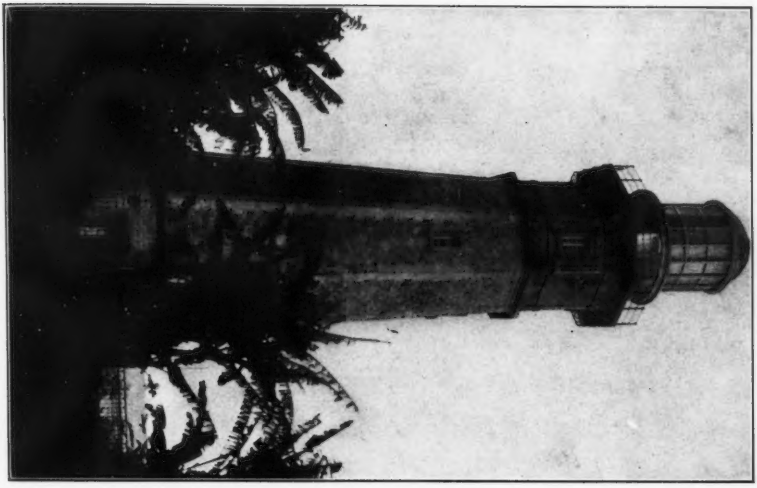


FIG. 1.—CAPE MELVILLE TOWER.

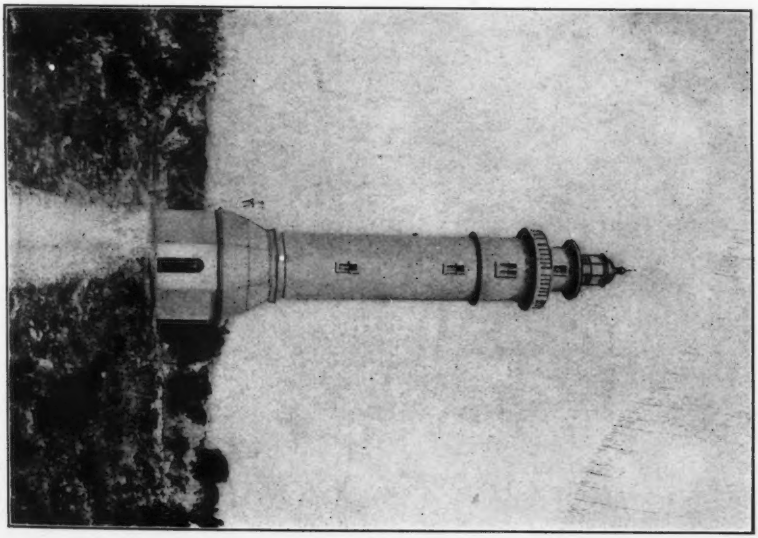


FIG. 2.—MANGUIN ISLAND TOWER.

tion, at a cost of several million dollars, of the protected deep-water harbor of Manila, begun many years before by the Spaniards. This was followed later by the creation of a Bureau which, as one of its chief functions, had charge of the lighthouse service of the Islands. The new officials proceeded at once to organize the lights already in existence, on the model of our home establishment, and to draw up plans for putting up new lights where most urgently needed.

When the American engineers first took up this matter of lighthouse construction, they were confronted with conditions differing greatly from those met in similar work in the United States. In some respects the problem appeared to be easier of solution. There are practically no fogs along the coasts of the Philippines, and both the transparency of the atmosphere and its refractive power are greater, according to the observations of the Spanish engineers, than along the Atlantic coast in temperate latitudes. These conditions make the lights themselves more effective, and render unnecessary the fog signals which are the most unsatisfactory parts of our modern lighthouse system. Then, too, a working season extending over the whole year, the absence of frost, and the cheapness of labor were factors which promised to be of material advantage in carrying on construction work. To offset these, however, were others, of the opposite kind—typhoons of frequent occurrence and of cyclonic violence along the paths of their centers; earthquakes of a mild character taking place constantly, but in certain districts reaching at times the most destructive intensity; the presence everywhere of the termite or white ant (the great destroyer of woodwork); the tropical humidity adding to the difficulty of protecting iron and steel properly; and the increased cost and long delays in obtaining many of the tools and materials of construction.

Labor was found to be cheap in about the same degree that it was efficient. A native carpenter, mason or blacksmith, at a dollar a day, will not do more than from one-half to one-quarter as much work as an American skilled workman, and will require more constant and careful supervision. Unskilled laborers, at from 20 to 50 cents per day, perform just about that much worth of work, according to American standards. One peculiar difficulty was met in securing workmen to go to some of the isolated lighthouse stations. The Filipino is strongly attached to his family, and many of the

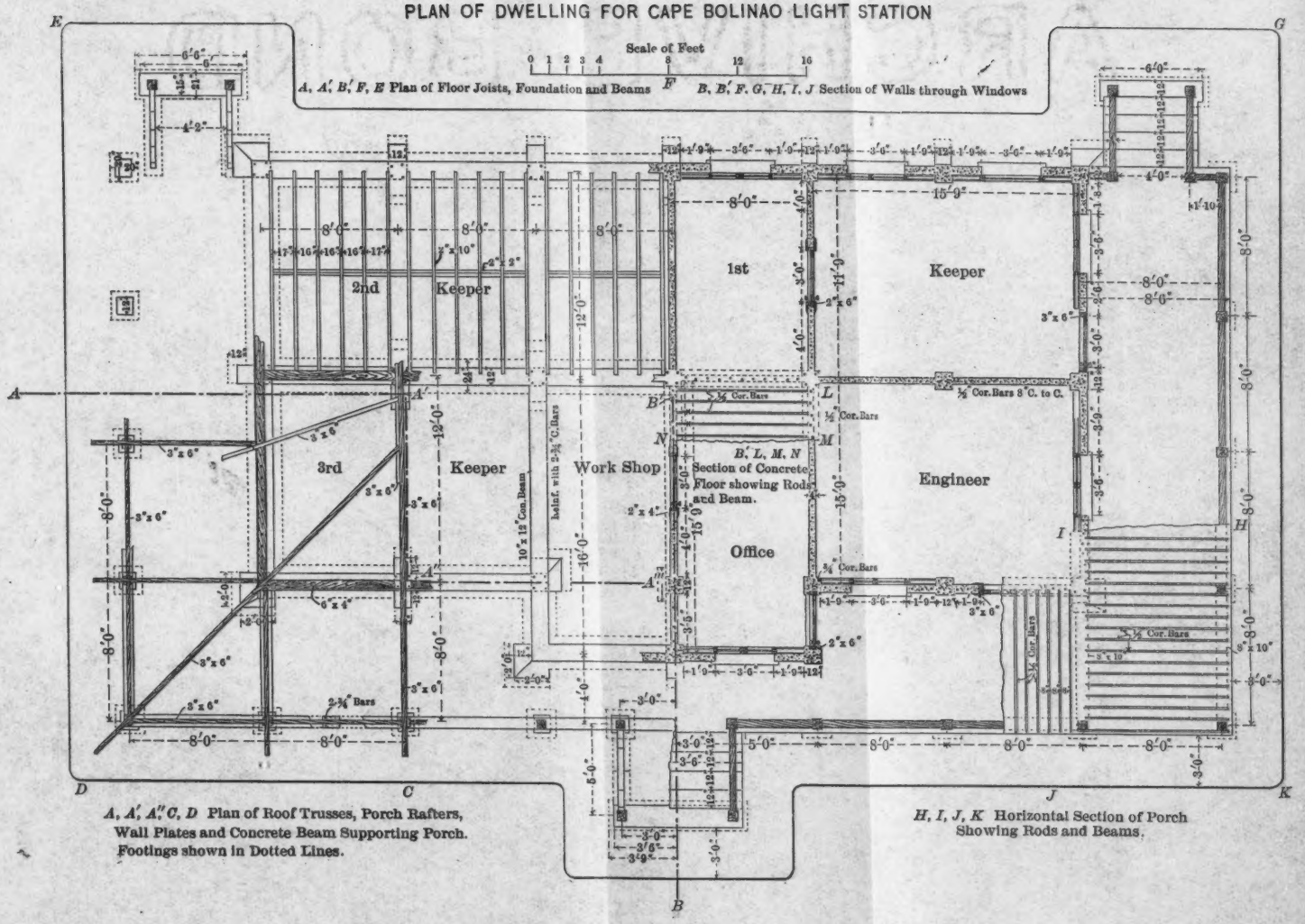
most desirable men refused to leave home for even a few months unless they could take their entire families with them. The difficulty of transporting and housing at the site such a mob of men, women, and children dwindled, however, when it was found that each family usually carried in a small sack its entire belongings, including the cooked rice to be eaten on the voyage, that they expected nothing more in the way of accommodations than sufficient room to lie down anywhere above or below deck, and that a few sticks of bamboo and bundles of "nipa" (palm leaves used for thatching walls and roofs) provided them with all the materials needed for building a home.

It should be mentioned that the labor conditions improved materially as time went on, as the lazy and incompetent were weeded out, and as those retained became used to steady work of the kind required. With fair treatment and proper training, it is believed that the Filipino can be developed into a more efficient and more reliable laborer than the negro of the South.

At the time the first insurrection broke out in the Philippines, in 1896, the Spanish Government was actively engaged upon an extensive programme of lighthouse construction, based upon carefully matured plans, which in the course of time would have provided an excellent system of lights. The disordered state of the country and the need of using all available funds for more urgent purposes caused the practical suspension of work in the latter part of 1896. It was not actively resumed by the Americans until six years later, and the first year was spent almost entirely in completing stations left in an unfinished condition by the Spaniards, and in repairing these wrecked or damaged by the insurgents.

The Spanish plans and records were turned over to the United States, so that when it came to new work the natural course was to carry out the projects they had so carefully worked out and which had back of them the benefit of the makers' long experience. The structures already in existence, at the stations which had not been disturbed, were nearly all of massive masonry—towers, keepers' dwellings, and even the oil houses and detached kitchens. All the buildings were of one story. They had resisted well the earthquakes and other destructive forces at work, except the white ant, the ravages of which had practically destroyed many of the floors, and

# PLAN OF DWELLING FOR CAPE BOLINAO LIGHT STATION



rendered insecure some of the wooden ceilings and roof trusses. A view of one of the best of the Spanish towers is shown by Fig. 1, Plate CXII, and an elevation and sections of a similar tower are shown by Fig. 1.

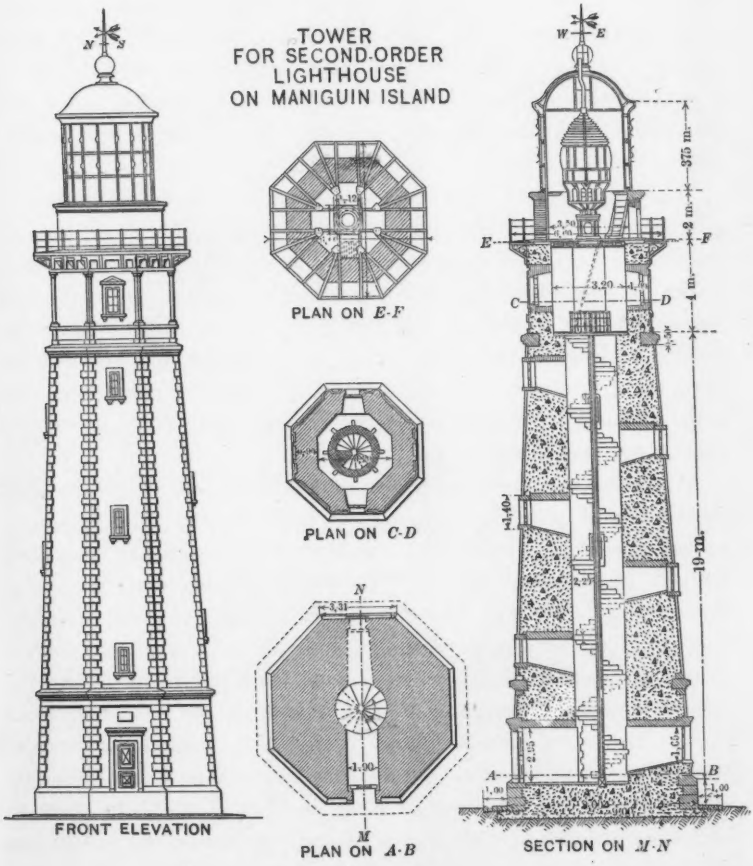



FIG. 1.

The plans of the first new dwelling to be erected called for walls 3 ft. thick and 15½ ft. high from foundation to roof truss, and this was typical of all. Such a structure naturally had nothing to fear from earthquake or typhoon, but the immunity was secured only

by the expenditure of a large amount of time and money, and economy in both was essential.

The Spaniards proceeded with their work in a more deliberate fashion than the writer felt justified in adopting. An interval of 4½ years elapsed between the time when work was started on the first-order light station shown by Fig. 1, Plate CXII, and the date when the light was first displayed. Even the smaller lights were usually from 18 to 30 months or more in building—and this after a year or two had been spent in making very elaborate plans and estimates, in having them passed on by various officials and boards, and in calling for bids.

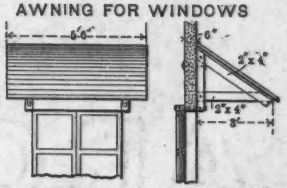
The Spanish lights are excellent structures, well fulfilling their purpose, but it had taken more than 10 years to build the greater number of them, and many a dark gap remained along the principal routes of commerce. It was decided that it was necessary to adopt methods which would provide these gaps with efficient lights as quickly as possible from the limited insular funds available for the purpose. One result of the system adopted may be mentioned here —the number of effective lights was increased by 60% in the two years, 1904 and 1905.

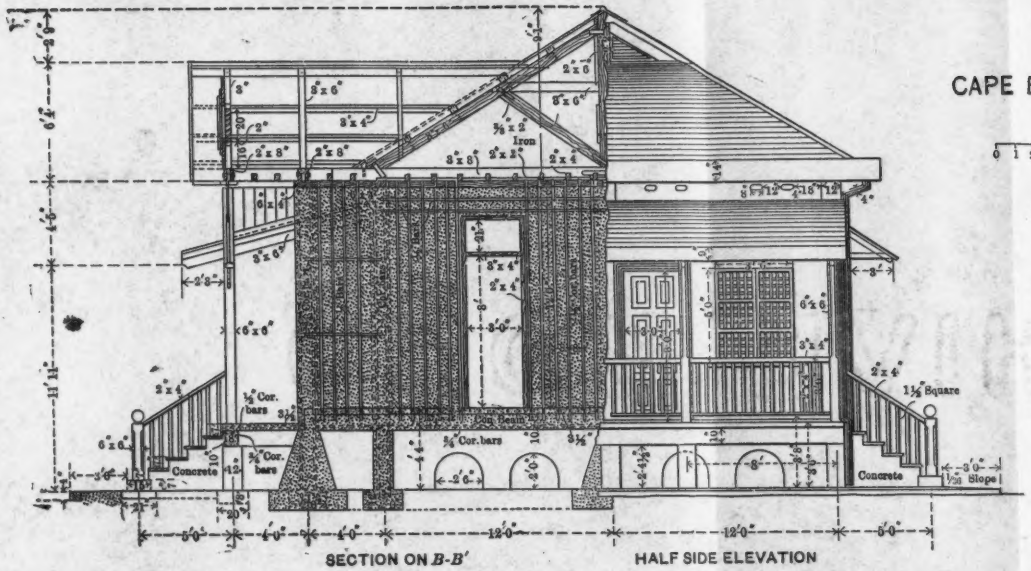
Attention was first directed to reducing the cost of the keepers' dwelling and the minor buildings at each station. The height of ceiling was lowered a few feet, the thickness of walls was decreased, the quality of mortar was improved by doing away with the use of lime; and concrete was used extensively in place of stone masonry. Two dwellings were built of timber, but the result was not satisfactory. The saving in first cost was not sufficient to offset the increased expense of maintenance and repairs, or the risk of destruction by fire, or of serious damage by the white ant, though special precautions were taken to reduce this last risk to a minimum by allowing no wood whatever to come in contact with the ground, by having an open, easily accessible and well-lighted space between the floor and the ground, and by making the lower parts of the posts, which were sunk in concrete piers, of the native hardwood "Molave." This wood has remarkable properties which make it an invaluable building material. It is very tough and durable, seems to be impervious to decay, even when placed on or in damp ground, and resists the attacks of both the white ant and the teredo. Its only

# DWELLING FOR CAPE BOLINAO LIGHT STATION

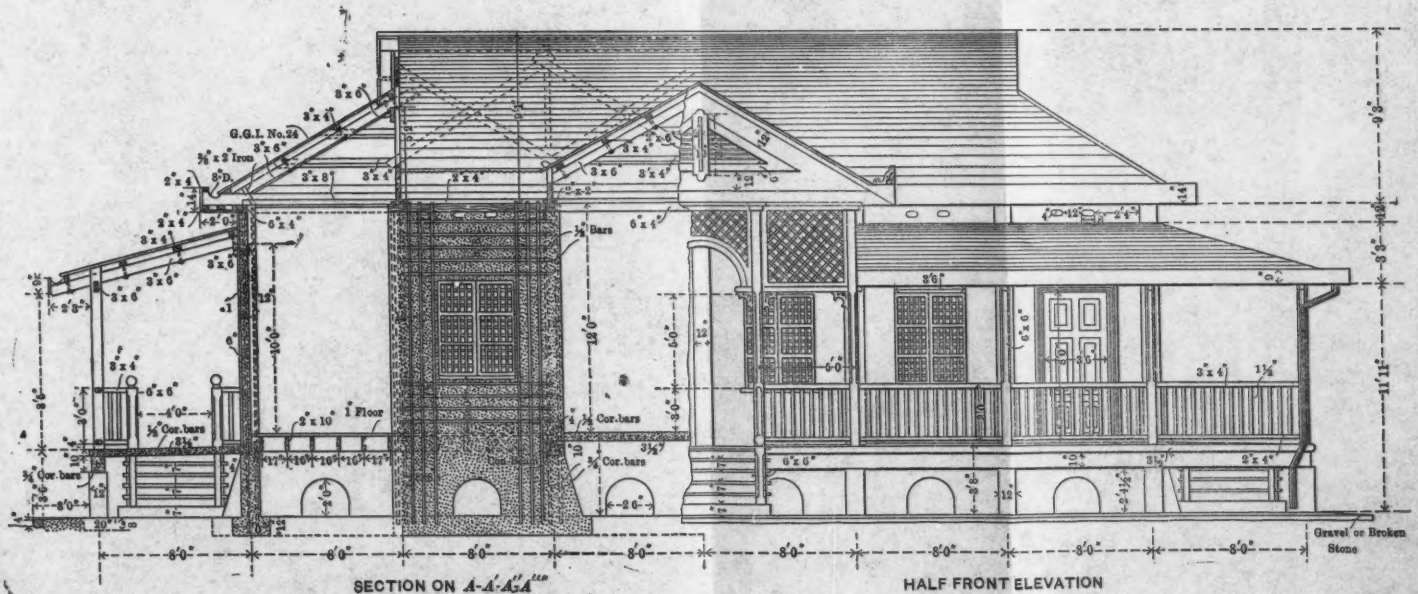
Scale of Feet
0 1 2 3 4 8 12 16

AWNING FOR WINDOWS




SECTION ON *B-B'* HALF SIDE ELEVATION




SECTION ON *A-A'-A''-A'''* HALF FRONT ELEVATION

drawback is the high price it commands, in spite of the fact that it is fairly plentiful throughout the Islands.

The next step was to reduce still further the thickness of the walls, making them of concrete and strengthening them with steel rods, in other words, adopting reinforced concrete construction. This was followed by the present type of dwelling, shown on Plates CXIII and CXIV, which consists essentially of columns of reinforced concrete, spaced 8 ft. apart, supporting the roof trusses, and joined by curtain walls of sufficient thickness to keep out rain and heat. It is believed that this form of construction will prove fully as strong and enduring as the more massive and costly Spanish style. It is designed to resist both typhoons and earthquakes. There is comparatively little woodwork, and that is placed so as to render it difficult for a fire to make headway rapidly or for the white ant to gain access to it. Repairs should be needed only at long intervals, and the cost of upkeep should be slight. Three keepers and their families are to occupy the dwelling; the kitchens, store room, oil room, etc., are in small detached buildings near it.

The following is abstracted from the instructions given to the workmen:

The drawings must be followed closely as to dimensions, materials and methods of construction. Should a departure from them be at any time deemed advisable, the overseer will ask the Lighthouse Engineer for authority to make the change, giving his reasons and a full statement of the facts in the case.

All changes made must be reported and shown in red on the blue prints.

Concrete for foundation work, piers, walls of buildings and cistern shall be mixed in the proportions of 1 bbl. of cement, 3 bbl. of sand, and 6 bbl. of broken rock having no dimensions greater than 2 in., excepting partition walls above the floor line, where the dimension of the rock shall not exceed 1½ in.

Concrete for floor beams shall be mixed in the proportions of 1 bbl. of cement, 2 bbl. of sand, and 4 bbl. of broken rock having no dimension greater than 1½ in.

The moulds under the concrete beams shall be supported rigidly for at least 3 weeks after the concrete is placed, and until all danger of sagging is passed. Posts on wedges may be used under the mould

planks so as to obtain exact alignment. The concrete in the beams shall be mixed in the proportion, 1:2:4. All other concrete shall be mixed in the proportion, 1:3:6.

The construction of the concrete of each beam shall be completed in a single day. The concrete shall be mixed wet, and as the moulds are filled, in 6-in. layers, cement mortar is to be first placed against the face to secure a smooth exposed surface. All concrete corners, both horizontal and vertical, shall be either rounded or beveled.

Forms for walls shall be made in narrow horizontal sections, and, immediately before the concrete is placed in a form, a coating of mortar (1 cement and 3 sand) shall be placed against the sides of the forms. The concrete shall then be thoroughly rammed.

The roof covering shall be of corrugated galvanized iron, No. 24, B. w. g.

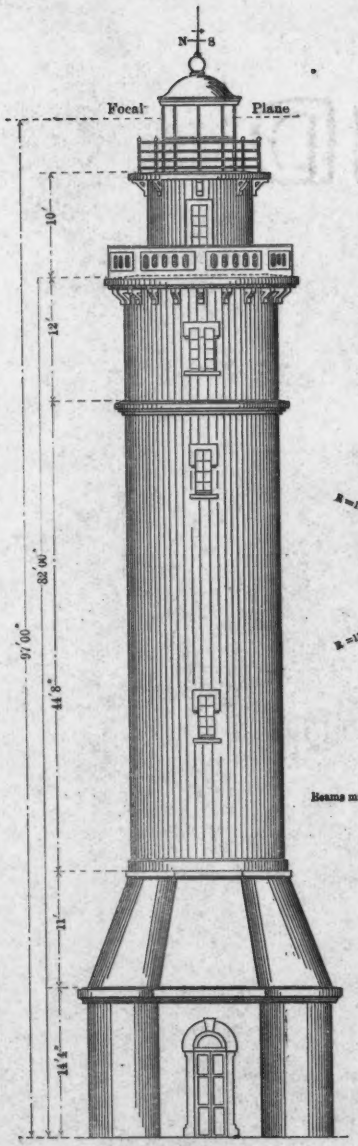
The more important question of tower design was not taken up until after that of the dwellings, for the reason that the parts (nearly complete) of three large steel towers, which had been bought in France by the Spaniards, were found on hand and were used by the Americans in three of the first new stations to be built.

The disadvantages of structural steel as compared with concrete, under the conditions existing, soon became apparent. The expense and length of time required to ship heavy steel members from Manila to the station, to unload them on a coast surrounded by coral reefs—usually in ships' boats or small scows and through the surf—and then to transport them from the beach to the site added largely to the already considerable first cost. The riveters available—Chinese, Japanese and Filipinos were all tried in turn—worked slowly, and even with constant watching did not do first-class work. The frequent handling resulted in much rubbing and scratching of the paint, and the appearance of many spots of rust; and the native painter, to whom looks are everything, could not be made to see the necessity of scraping off the rust before applying the paint. It is this tendency of the native mind that makes the durability of the steel towers doubtful, as the lighthouse keepers, who are charged with keeping them properly painted, are all Filipinos.

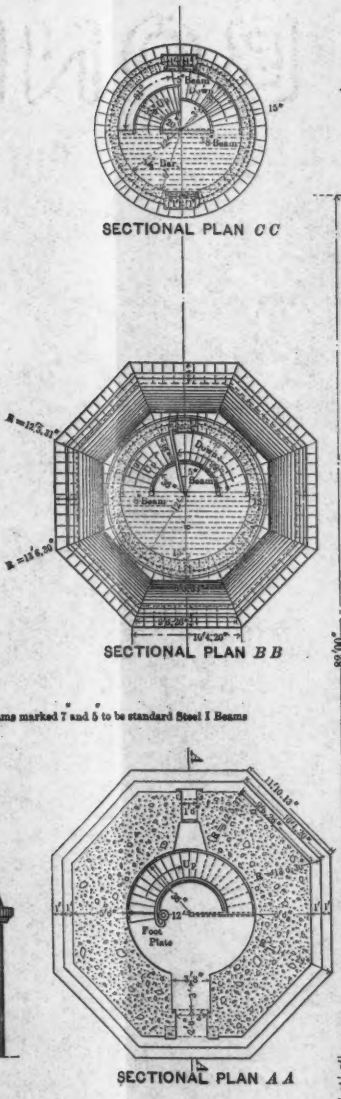
Concrete towers, on the other hand, require but little attention, and cost practically nothing for repairs, an important consideration

PLATE CXV.
PAPERS, AM. SOC. C. E.
NOVEMBER, 1906.
COSBY ON
LIGHTHOUSE CONSTRUCTION.

# TOWER
# MANIGUIN ISLAND
# LIGHT STATION




ELEVATION


Beam
15"
Bar
Beam
Beam
Beam



when all materials and most of the workmen have to be transported long distances in special boats. Then, too, all the projected lighthouses were to be erected either on high and rocky sites or on low-lying coral islands, and in both cases all the materials for concrete, except cement, were to be found in the immediate vicinity. By using steel rods to reinforce the concrete, the total mass of the latter, in a tower of given height, could be safely reduced, the upper walls of the tower could be made thin and light, and the base section broad and heavy, thus lowering the center of gravity and increasing the stability against overturning by earthquakes. The steel rods also served to bind all parts of the tower solidly together, and thus enable it to resist better the quick vibratory movements, made up of vertical as well as horizontal components, which have proved most destructive in severe earthquakes.

All these considerations led to the adoption of reinforced concrete as the material to be used in the construction of the higher towers to be erected. The accepted designs of three of these are shown on Plates CXV, CXVI and CXVII, and a view of the first in its finished condition is shown by Fig. 2, Plate CXII.

This tower was erected in place of the one designed by the Spanish engineers, shown by Fig. 1. Though its focal plane is 5 ft. higher than the latter, it contains less than half the quantity of masonry required by the Spanish plan. The cost of the metal reinforcement amounts to barely one-tenth of the cost of the concrete saved. The Spanish design, however, gives a factor of safety against overturning by wind pressure of more than 10, while the new tower has a factor of only 7, though this is believed to be ample. On the other hand, its center of gravity is about 7 ft. lower than that of the lower Spanish tower, giving it a greater stability in the case of earthquakes.

The following details of the Maniguin Island tower may be of interest: The vertical reinforcement throughout is of $\frac{3}{4}$-in. corrugated steel bars, the spacing being about 6 in. in the walls, up to the floor of the watch-room, and about 12 in. from center to center in the wall of the watch-room. All these bars are set about 3 in. from the outer surfaces of the walls.

The circular horizontal reinforcement throughout the tower is of $\frac{1}{2}$-in. round steel bars, spaced 12 in. from center to center, next to

and inside of the vertical bars. The lantern gallery floor is reinforced with two ½-in. round steel bars placed 3 in. and 15 in., respectively, from the outer edge of the gallery.

The horizontal reinforcement in the floors of the lantern and watch-room, and in all stair landings is of ½-in. corrugated steel bars, spaced 6 in. from center to center, and 1½ in. above the bottom of each floor. These bars extend about 12 in. into the walls on each end.

The radial reinforcement of the watch-room gallery is of ½-in. corrugated steel bars, spaced as shown on the sectional plan on *EE*, that is, about 6 in. from center to center at the interesctions with the vertical ¾-in. corrugated bars.

The brackets under the lantern and watch-room galleries are reinforced with ½-in. corrugated steel bars.

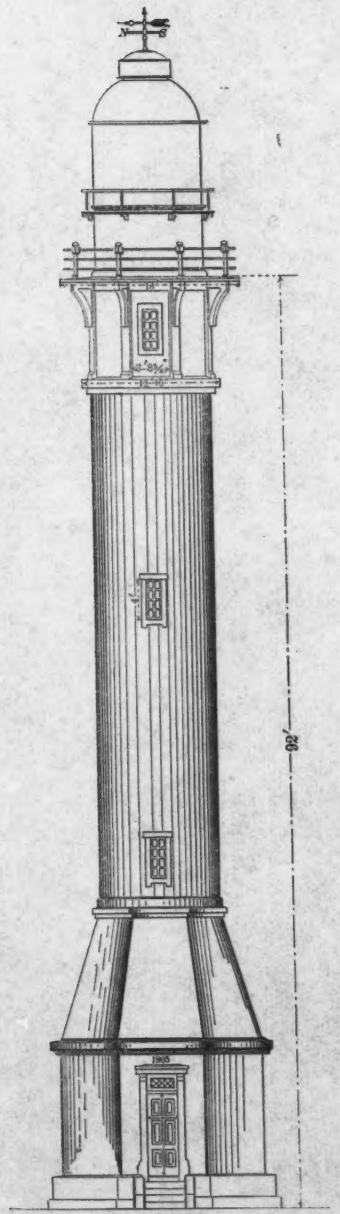
The reinforcement of the parapet on the watch-room gallery consists of one ½-in. corrugated steel bar over each bracket vertically, and one circular ½-in. round steel bar 3 in. from the top.

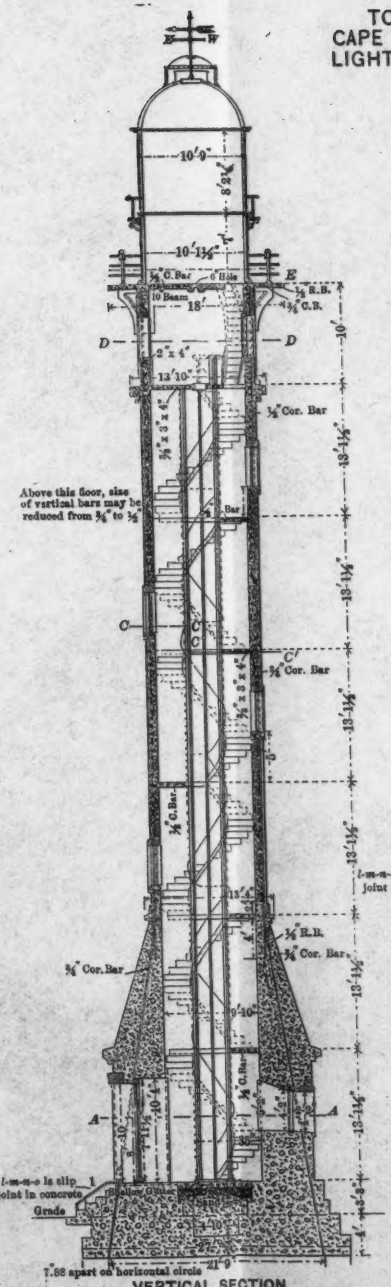
The proportions of the concrete in the blocks, brackets, door and window trimmings, etc., were 1 part cement, 2 parts sand, and 4 parts broken stone. The proportions in other parts were 1 part cement, 3 parts clean sand and 6 parts broken stone or gravel, no piece of which had a greater dimension than 2 in. The concrete was carefully and thoroughly mixed, and was placed in 6-in. layers, each of which was well rammed. Sufficient water was added to make the concrete so wet that it quaked moderately under the rammer. All concrete surfaces more than 12 hours old were wet and then covered with a ½-in. layer of mortar before fresh concrete was placed on them.

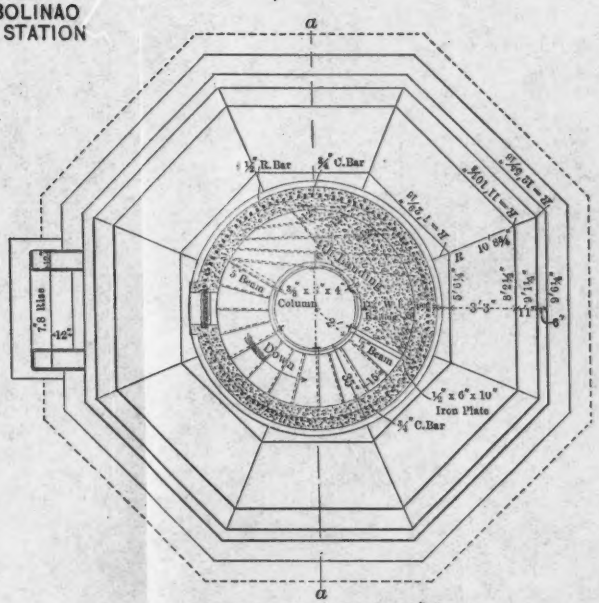
The steel bars were not painted, but all rust scales were ordered to be scraped off just before the bars were placed in the concrete. In every case the metal was covered with at least 1½ in. of concrete.

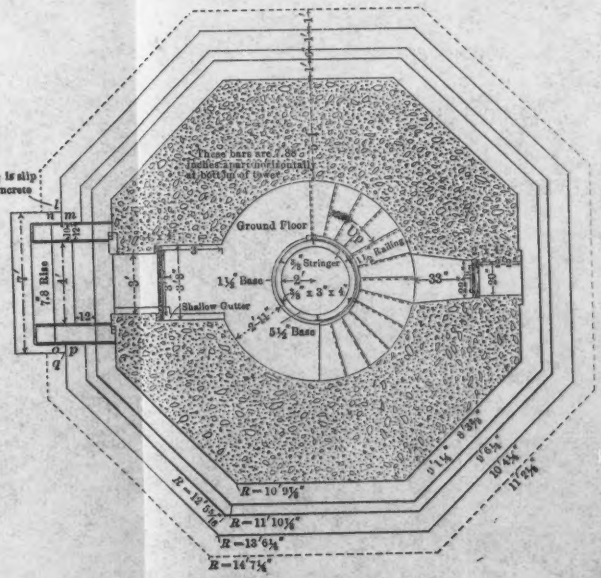
The vertical corrugated bars were in lengths varying from 20 to 27 ft., and their joints were staggered so that adjacent ones occupied several different planes. All bars, vertical and horizontal, overlapped from 24 to 30 in. at the ends, and were wired together. Great care was taken to make all vertical rods absolutely straight and to align them accurately. The horizontal and vertical bars were wired together at each intersection with one another.

# TOWER CAPE BOLINAO LIGHT STATION



The erection of the second tower (Plate CXVI) has just been completed at Cape Bolinao, on the west coast of Luzon. It is not built on solid rock, like the first, which has its vertical reinforcing bars prolonged below the base to act as anchor rods. The masonry portion of the two towers is of the same height, but the second is of simpler design, and requires a somewhat smaller quantity of concrete. Simplicity of construction was a factor having paramount influence in determining the lines of the tower. Laborers skilled in reinforced concrete construction were unobtainable, therefore men of the regular force had to be educated to the special requirements of this kind of work; even to the American overseers in charge it was comparatively new, and, as the site is isolated and difficult of access, frequent inspections from the head office could not be made. Lumber is expensive, and to require many or elaborate forms would add materially to the cost, and delay the time of completion. The design of tower selected, consisting essentially of a long, hollow, concrete cylinder resting on a spreading base, each face of which was a plane surface, required comparatively few forms, and of such a simple character as to give little excuse for mistakes of any kind. As an additional guard against these and against defects due to carelessness or ignorance, however, all factors of safety were made large, and the quantities of concrete and of metal reinforcement were both increased beyond what would be required in ordinary construction. The cornices, the door and window openings, and the bracketed balcony of the lantern are the only features that relieve the simplicity of the design or call for the exercise of more than the most ordinary care or ingenuity in making the forms and setting the steel bars.

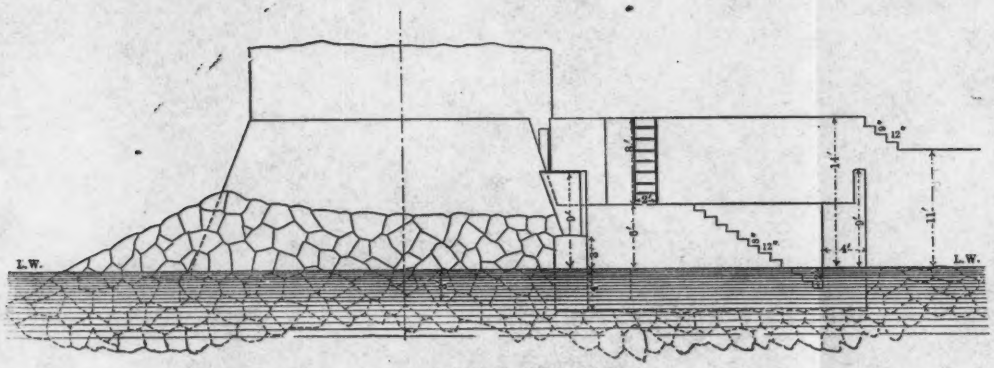
The upper part of the tower was given a circular rather than a polygonal cross-section in order to diminish the effect of the wind, which, for purposes of computation, was assumed to exert a pressure on the cylindrical surface equal to half that exerted on a vertical section through the axis normal to the direction of the wind. The maximum wind pressure was assumed as 70 lb. per sq. ft. This is undoubtedly high, but as a wind velocity of more than 120 miles per hour has been recorded at the Manila Observatory during a typhoon, and as the tower is to stand in an exposed position, it was thought advisable to be on the safe side. The Spanish engineers

sometimes adopted a maximum wind pressure as high as 80 lb. per sq. ft. in justifying their designs. With a pressure of 70 lb. per sq. ft. the smallest factor of safety of any section against overturning, under the assumptions made, is about 6¾, while the greatest compression on the concrete (at the foot of the cylindrical section) would be 186 lb. per sq. in. In all these calculations the weight of concrete was taken at 140 lb. per cu. ft., which is a pound or two less than the weight found by actual measurement of concrete at other stations where the sand and stone are about the same as those to be used in this tower.

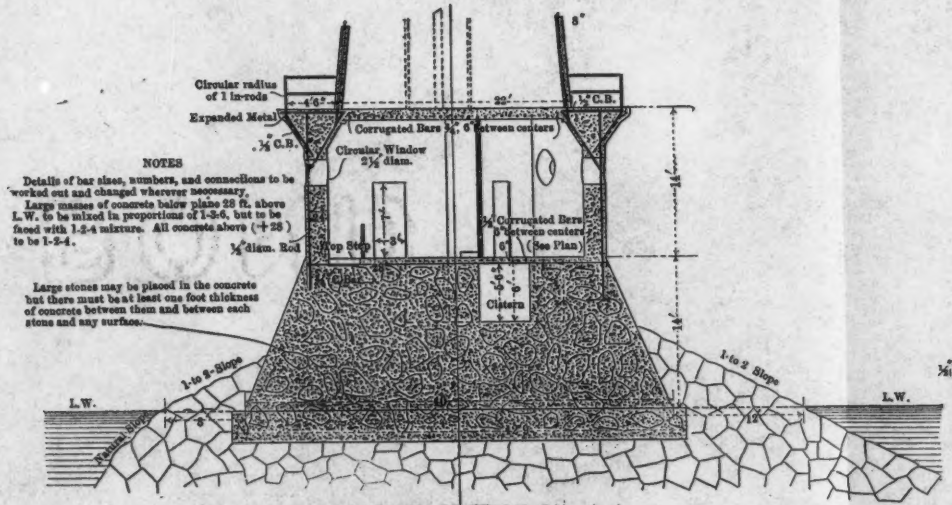
When it comes to earthquakes, so little of a definite nature is known of them, and their effects vary so much with the locality, that it is out of the question to attempt to calculate even approximately the ability of the tower to resist them. In small earthquakes, the vertical component of the motion is often imperceptible, but in destructive shocks, buildings are not only subjected to horizontal stresses, but are also tipped and rocked, and the ground may describe elliptical or other curved paths. The destruction wrought in high structures is usually the result of the rapidity with which vibratory movements are communicated to them. When the lower part of a tower is suddenly moved forward, the inertia of the upper part makes it tend to remain at rest, and a fracture between the two may result. The lighter the upper part the less danger is there of damage from this cause and of overturning from tipping. Hence the importance of placing the center of gravity as low as possible. The stability of a well-built tower, against earthquakes, may be considered as an inverse function of the height of the center of gravity above the ground, and as a direct function of its horizontal distance from the edge about which overturning may take place. The results of numerous recent experiments in Japan on the stability of columns is summed up by Baron Kikuchi as follows:

"For given values of height and external dimensions, a hollow column has a greater seismic stability than the corresponding solid one, the sides or walls in the former column being sufficiently thick and rigid for it to be regarded as a single structure."

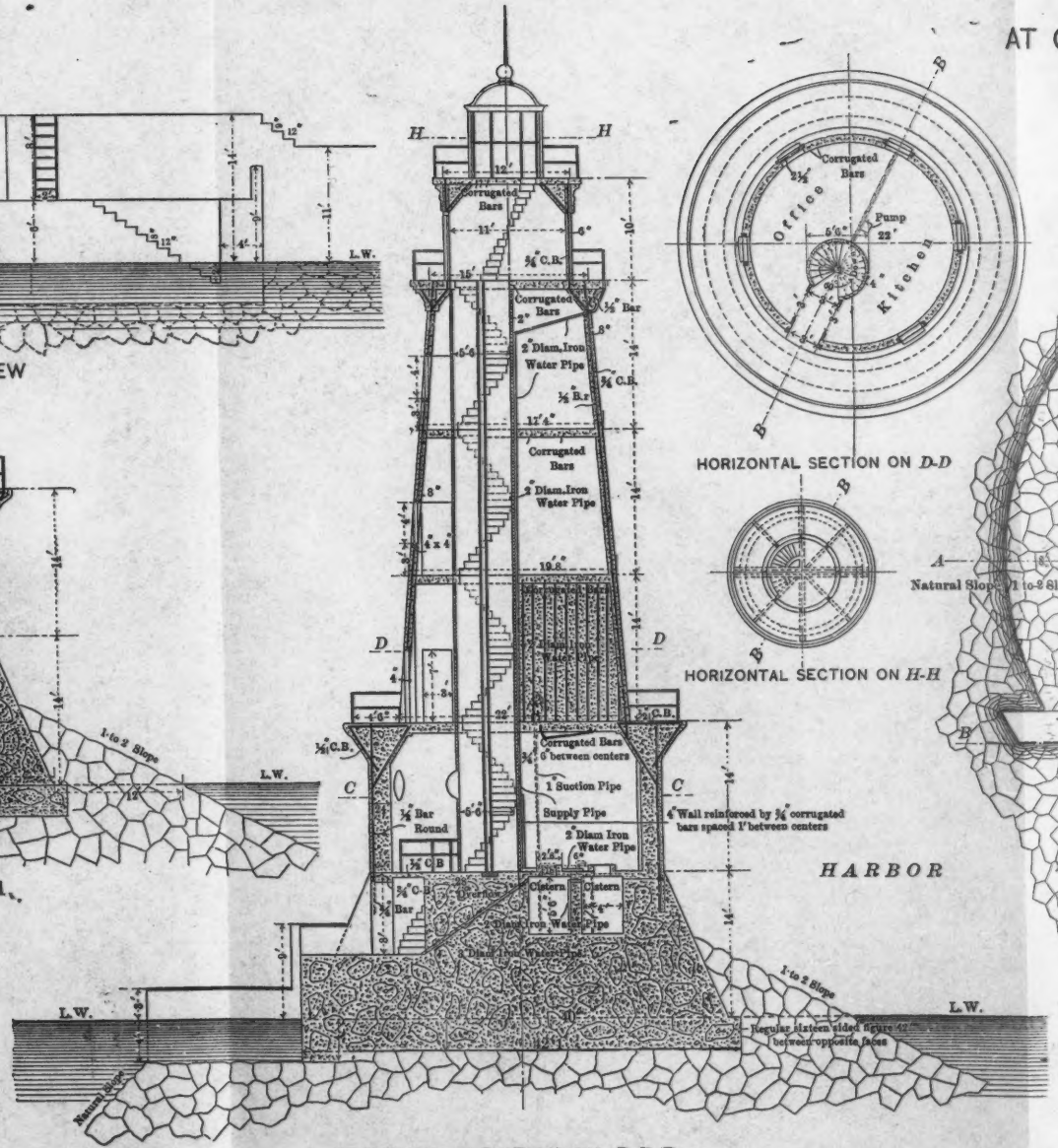
The effort was made to keep the foregoing considerations well in mind in designing the Cape Bolinao tower, at the same time having due regard to simplicity and rapidity of construction.




HARBOR SIDE VIEW




VERTICAL SECTION ON *A-A*.




SECTIONAL ELEVATION ON *B-B-B*

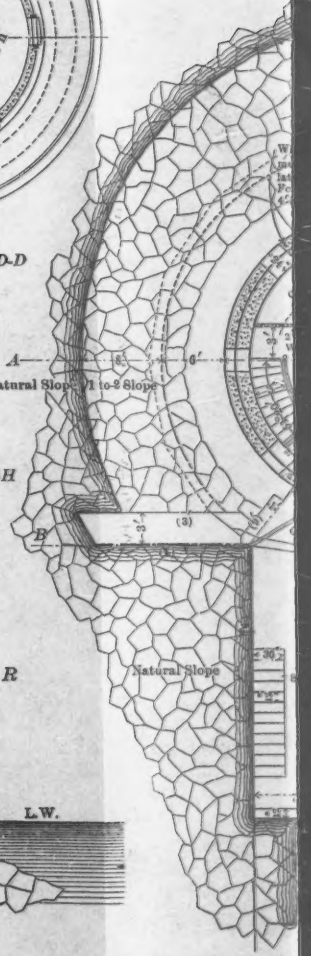



HORIZONTAL SECTION ON *D-D*

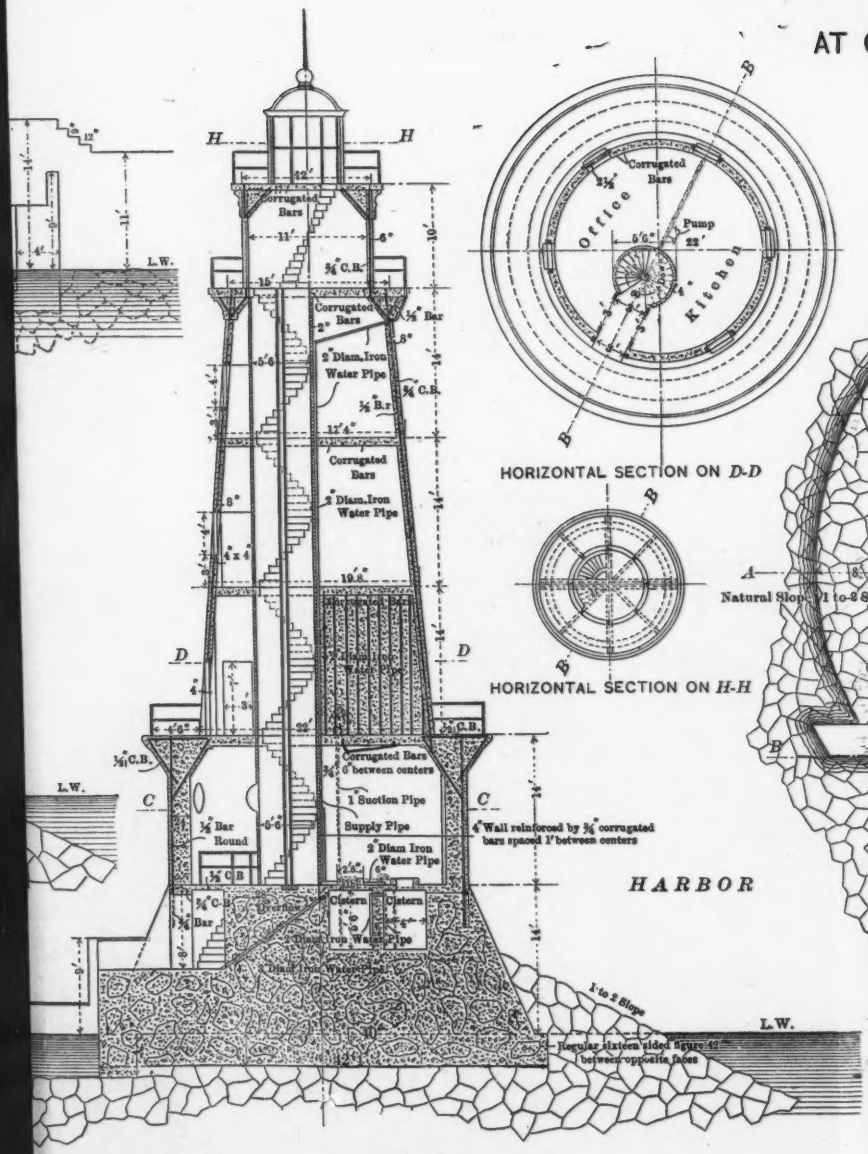



HORIZONTAL SECTION ON *H-H*

PROPOSE
AT OUTER EN

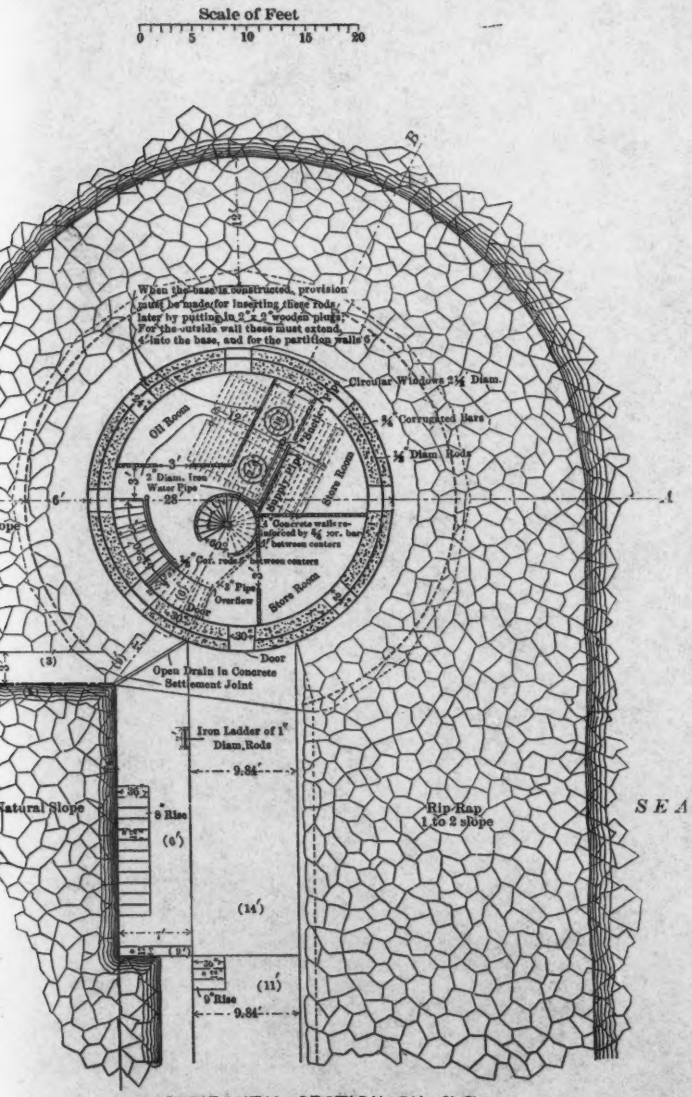


PROPOSE
AT OUTER EN




SECTIONAL ELEVATION ON *B-B-B*

# PROPOSED LIGHTHOUSE TOWER
# OUTER END OF MANILA BREAKWATER.




HORIZONTAL SECTION ON *C-C*

As already stated, the motions due to an earthquake are of too complicated and uncertain a nature to attempt to calculate the resisting strength of the tower; but, as a check on the quantity of reinforcement, the following method was used in computing the factor of safety against a simple tipping movement.

An old instrument in the Manila Observatory once recorded an inclination of 13° from the vertical, due to an earthquake, and this was the greatest inclination of which an authentic record could be found. The observers, however, place little reliance on it, considering it much too great; undoubtedly a good part of the movement of the instrument was due to the throw imparted by the quickness of the impulse given; but, in the absence of more reliable data, and as a basis for calculations making little pretense to accuracy, this inclination of 13° was assumed as a fair measure of the simple overturning force to be resisted.

Let $W$ = the weight of the tower,

$G$ = the height of the center of gravity above the base,

$D$ = the distance from the center of the base to the edge about which overturning may occur.

Then, when the tower is inclined 13° from the vertical,

$W \sin. 13° \times G$ = overturning moment.

$W \cos. 13° \times D$ = resisting moment.

$$\text{Therefore, the factor of safety} = \frac{W \cos. 13° \times D}{W \sin. 13° \times G} = \frac{D}{G} \cot. 13°$$

$$= \frac{13.5}{25.6} \cot. 13° = 2\tfrac{1}{3}.$$

This is the factor of safety against overturning about an edge of the base.

At any other section, as at the base of the cylindrical portion, both the longitudinal component of the weight and the tension of the reinforcing bars act to resist overturning, and the factor of safety must be computed in a different manner. This is done by using the formula, $P = \frac{My}{I}$, in which

$P$ = the tension (or compression) on a unit area of the section,

$M$ = the weight above the section $\times$ sin. 13° $\times$ the height of the center of gravity of the portion above the section,

$y$ = 5 ft. 5 in. = the radius to the center of the sectional ring,

$I$ = the moment of inertia of the sectional ring.

Substituting the proper values in the formula, $P = 31\,100$ lb. per sq. ft. is obtained for the maximum tension due to the inclination of the tower. Part of this is taken up by the pressure per square foot, due to the weight above ($10\,655 \times \cos. 13°$), leaving 20 808 lb. to be resisted by three ¾-in. corrugated bars, having a sectional area of 0.37 in. and a minimum elastic limit of 50 000 lb. per sq. in. These give a factor of safety of 2.7, which is slightly greater than at the base.

It may be noted that, under the above assumptions, the maximum compression on the concrete at any edge would be a little more than 300 lb. per sq. in., which is within the allowable limit. It should be repeated, however, that none of these computations pretends to measure the resistance of the tower to earthquake shocks—they were useful in proportioning its parts.

Plate CXVII shows the adopted design of a reinforced concrete lighthouse, on a rubble-mound base, which is to form the outer end of the new Manila breakwater. In designing this, the same assumptions as before were made, except that the weight of unsubmerged concrete was taken as 150 lb. per cu. ft., as a heavier stone is to be used for the aggregate. The frictional resistance of the mass to sliding was taken as 65% of its weight, allowing for submergence up to 14 ft. above mean low water, and the maximum wave pressure as 1 700 lb. per sq. ft. Both figures, of course, are mere assumptions based on the values found at places where the conditions were similar to those at the locality in question.

It is the intention to allow ample time for the consolidation of the breakwater substructure, which was only recently built, before beginning the erection of this tower. The construction of its foundation, however, has been completed.

Too short a period has elapsed since the completion of the other two reinforced concrete towers to warrant claims being made that experience has proved the soundness of their design, though one of them has already passed unscathed through a typhoon during which the recorded velocity of the wind in Manila exceeded 100 miles per hour. That they will successfully withstand the attacks of typhoon and earthquake, and cost little for maintenance, the writer has no doubt, provided, of course, reasonable care and skill were used in their construction.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## RAINFALL, AND RUN-OFF IN STORM-WATER SEWERS.

By Charles Emerson Gregory, Assoc. M. Am. Soc. C. E.

To be Presented February 20th, 1907.

The object of this paper is to amplify and bring together matter contained in previous discussions of this subject, and to propose a more rational method of solution.

Unfortunately, the experimental data presented are not entirely conclusive, and it is hoped that this paper may inspire the making of further experiments, and induce other investigators to submit additional data for comparison.

Among the earliest data which gained the notice and, for a long time, the approval of the engineering profession are the observations of rainfall and run-off made from gaugings in the sewers of London, England, in 1854, by Roe, Bidder, and Bazalgette, and interpreted by Hawksley. Very little is definitely known about the details of these experiments. Two definite conclusions, however, seem to have been reached. One was that the run-off during a storm is about 40 to 54% of the rainfall; and the other, that 1 in. of rain per hour is a safe maximum for which to provide. The latter conclusion, especially, seems to have been for a long time generally accepted both in America and in England, and still has such a firm hold on

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

the fancy of those who have not studied the matter deeply that they cannot look at the subject from any other viewpoint.

These general statements have been reiterated by authorities in many textbooks, and in most cases without the qualifications necessary for a proper understanding of their meaning. It is not usually stated whether the 40 to 54% run-off is a rate of run-off (the fact most necessary to know in designing a drain); or a total run-off; or whether it is a percentage of the maximum rate of rainfall; or of an average rainfall; or of the total rainfall in a single storm; or of the rainfall in an hour. The maximum rate of 1 in. per hour was apparently taken to be of equal weight and effect, whether it fell at a uniform rate, or whether it all fell in 15 or 20 min.; and was supposed to be the same for all water-sheds of whatever size or shape.

From these two general conclusions, supplemented probably by personal observations, was developed the empirical formula, of the type used by Hawksley and Adams, in which the run-off varies with the size and slope of the water-shed, but in which Jupiter Pluvius was so firmly bound by the inch-per-hour tradition that it was never suspected that he would deviate from the path prescribed for him.

The following notation will be used throughout this paper to designate the various factors:

$Q$ = Discharge, in cubic feet per second;
$A$ = Drainage area, in acres;
$S$ = Slope of surface, or of sewer, in feet per thousand;
$R$ = A rainfall coefficient, sometimes considered to be a maximum rate for a short period, in inches per hour; sometimes as the average rate per hour; but usually not well defined;
$N$ = The length, in feet, in which the sewer falls 1 ft.;
$d$ = Diameter of circular sewer, in inches;
$D$ = Diameter of circular sewer, in feet;
$r$ = Hydraulic mean radius;
$v$ = Velocity, in feet per second;
$s$ = Sine of slope of sewer;
$C$ = A coefficient, depending upon the extent of impervious surface, or the ratio of rainfall to run-off;
$i$ = Intensity of rainfall, or rate, in inches per hour;
$t$ = Time, in minutes.

Hawksley's formula, in its original form (derived from Roe's tables*), is as follows:

$$\log. d = \frac{3 \log. A + \log. N + 6.8}{10}.$$

If $N$ is replaced by its equivalent, $\frac{1}{s}$, and the formula is divested of its logarithms, it becomes

$$d^{10} = 6\ 309\ 574 \frac{A^3}{s},$$

and, if $d$ is reduced to feet, then $d = 12\ D$, and

$$D^{10} = 0.0001019 \frac{A^3}{s}.$$

This formula is still used in the Borough of Brooklyn, New York City, except that, for the large sewers, the last term of the numerator is changed from 6.8 to 8.0, and would therefore appear as

$$d^{10} = 100\ 000\ 000 \frac{A^3}{s},$$

and

$$D^{10} = 0.001615 \frac{A^3}{s}.$$

This formula may be transcribed, so as to give $Q$ in terms of $A$ and $S$, by substituting in $v = c\sqrt{r\,s}$, the fundamental formula for the flow of water, thus:

If $c = 100$, then $v = 50\sqrt{D\,s}$, and $Q = \frac{A - D^2\,v}{4}$.

Therefore, $Q = 39.27\sqrt{D^5\,s}$,

and $$D^{10} = \left(\frac{Q}{39.27}\right)^4 \times \frac{1}{s^2}.$$

But, as $$D^{10} = D^{10}\left(\frac{Q}{39.27}\right)^4 \times \frac{1}{s^2} = 0.0001019 \frac{A^3}{s^2},$$

and $$Q = 3.946\ A \sqrt[4]{\frac{S}{A}},$$

and since $$s = \frac{S}{1\ 000},$$

$$Q = 0.7\ A \sqrt[4]{\frac{S}{A}}.$$

In the same manner,

$$D^{10} = 0.001615 \frac{A^3}{s}$$

* Report of Commission on Metropolitan Drainage, London, 1857.

reduces to $Q = 1.4\ A \sqrt[4]{\frac{S}{A}}$, which is twice as great a value for $Q$ as in the original form. This change may be explained by introducing a rainfall coefficient, the value of which in the original form was unity and now becomes 2. The general form may then be written:

$$Q = C\ R\ A \sqrt[4]{\frac{S}{A}}$$

in which $C = 0.7$ and $R = 1$ in the original form, or 2 in the amended form, and is supposed to provide for a rainfall of 2 in. per hour, but the length of the period is not stated.

From this formula as a basis have been developed nearly, if not quite, all the later modified forms of the empirical exponential formulas.

The formula by the late Julius W. Adams, Past-President, Am. Soc. C. E., as published in 1880, was deduced as follows: In the expression,

$$D^5 = \left(\frac{Q}{39.27}\right) \times \frac{1}{s},$$

as previously developed from the formulas for the flow of water, in the demonstration of the Hawksley formula, the exponent of $D$ is changed from 5 to 6, and for $Q$ is substituted $\frac{A}{2}$, on the assumption that $\frac{1}{2}$ in. of rain per hour will reach the sewer, thus giving

$$D^6 = \frac{A^2}{6168\ s},$$

and, for any other value for $R$ than unity, substitute $\frac{A\ R}{2}$ for $Q$,

then $$D = \sqrt[6]{\frac{A^2\ R^2}{6168\ s}},$$

but $D$ is also equal to $\sqrt[5]{\frac{Q^2}{1542\ s}}$,

therefore $$\sqrt[6]{\frac{A^2\ R^2}{6168\ s}} = \sqrt[5]{\frac{Q^2}{1542\ s}},$$

whence $$Q = 1.035\ R\ A \sqrt[12]{\frac{s}{A^2\ R^2}}.$$

If $\frac{S}{1\,000}$ be put in place of $s$, then

$$Q = 1.837\ R\ A \sqrt[12]{\frac{S}{A^2\ R^2}}.$$

The Bürkli-Ziegler formula is identical in form with the reduced Hawksley formula, and has been used extensively in Europe. It differs from the original Hawksley formula only in that the values of the constants, $C$ and $R$, have been modified to a greater or less extent.

As American engineers began to investigate this important subject on their own account, and as designs made on the old theories began to prove inadequate, the so-called rainfall coefficient, originally put down as unity, was increased in order to fit more nearly the new conditions. These changes were brought about by several more or less complete scientific investigations, and, while no attempt will be made to give herein an accurate or complete history of this part of sewer design, a few important mile stones along the way will be noted.

One of the first investigations was by R. E. McMath, M. Am. Soc. C. E., on the sewers of St. Louis, Mo. The details* will not be given here, but only a brief summary of the essential points and the results.

A tabulation was made showing all existing trunk sewers and branch sewers, with their capacities calculated by Kutter's formula, the number of acres tributary, the average slopes of the flow lines, and brief descriptions of the surface conditions. The St. Louis sewers had been built from time to time under the direction of different engineers, each of whom had his own peculiar ideas of what was required; consequently, the ratio of area drained to sewer capacity had a wide range.

Next, a record of the adequacy of each sewer was made, the capacities, in cubic feet per second, being plotted as ordinates, and the tributary acreages as abscissas, and all inadequate points were marked. A curve, including all inadequate points, was then drawn, and its equation was found to agree with the following formula, now commonly known as the McMath formula:

$$Q = A\,C\,R\sqrt[5]{\frac{S}{A}}.$$

To make this formula fit the curve described, the following values were given to the different factors:

$$C = 0.8,$$
$$R = 2.75,$$
$$S = 15.$$

* *Transactions*, Am. Soc. C. E., Vol. XVI, p. 179.

Below this curve there was a kind of neutral zone in which some points were inadequate and some were adequate, on account of flat slopes, undeveloped areas, etc.

In most cases it was found that, by applying the correct values for the slope and the surface coefficient, the formula gave approximately correct results.

This formula, as far as the writer knows, is only an empirical modification of Hawksley's exponential formula, and is typical of those most generally used.

Soon after this, two other investigations were made: one by E. Kuichling, M. Am. Soc. C. E., and the other by Rudolph Hering, M. Am. Soc. C. E.

Mr. Kuichling's observations related to sewers draining well-developed territory, a moderately large percentage of which was impervious; territory only partially developed; and residential neighborhoods having a small percentage of impervious area. The observations, like those by McMath, were made without the aid of clock gauges for either the rainfall or the depth of flow in the sewers, but the rate of rainfall for short intervals was carefully timed by observers stationed at the gauges. The depths of flow in the sewers were recorded by a simple device which gave maximum depths only. The observations, however, were taken with such a clear understanding of their significance and limitations that the essential features were obtained with as great accuracy as was possible with the apparatus used. The results of many of these gaugings are shown in Tables 2 and 3.

Mr. Kuichling was the first to give a rational method of analysis of the problem, and the following conclusions are condensed from his paper:*

1.—The percentage of rainfall discharged from any given drainage area is nearly constant for heavy rains lasting equal periods of time.

2.—This percentage varies directly with the area of impervious surface.

3.—This percentage increases rapidly, and directly or uniformly with the duration of the maximum intensity of the rainfall, until a period is reached which is equal to the time required for the

* *Transactions*, Am. Soc. C. E., Vol. XX, p. 1.

concentration of the drainage waters from the entire area at the point of observation; but, if the rainfall continues at the same intensity for a longer period, this percentage will continue to increase at a much smaller rate.

4.—This percentage becomes larger when a moderate rain has immediately preceded a heavy shower on a partially permeable territory.

5.—The sewer discharge varies promptly with all fluctuations in the intensity of the rainfall.

6.—The sixth conclusion shows the unreliability and the danger of making general applications of the standard exponential formulas, and suggests the following method of solution, in which $a$, $b$, and $c$ are empirical constants, and $t$ is the duration of the rain, in minutes:

*First.* $Q = A\ C\ R.$

*Second.* $C = a\ t.$

*Third.* $R = b - c\ t.$

*Fourth.* $Q = A\ a\ t\ (b - c\ t).$

In the latter expression, $Q$ and $t$ are the only variables, and, placing the first derivative equal to 0,

$$A\ a\ (b - 2\ c\ t) = 0, \text{ and therefore:}$$

*Fifth.* $t = \frac{b}{2\ c}$ = the time for the absolute maximum rate of run-off.

The results of Mr. Hering's investigation, made in New York City, in 1888, have not been published. The writer believes that Mr. Hering was the first to use clock gauges for both rainfall and run-off. His observations are very briefly described as follows:

"A typical, built-up and paved section* in the lower part of New York City was selected. A self-registering gauge was erected to record the flow from an area of 221 acres. The interior of the sewer was carefully examined, and found to be regular and suitable for the safe application of a slope formula, and a value for the coefficient of roughness was determined. A survey of the water-shed was made, and its slope was found to be regular and the average grade was 7 ft. in 1 000. The average length of the sewers from the periphery of the district to the gauge was 2 886 ft., and the maximum distance about 4 800 ft. The total area of the dis-

* This section was drained by what is known as the Sixth Avenue sewer, and, roughly, is bounded on the south by First Street, on the north by Sixteenth Street, on the east by Broadway, and on the west by Eighth Avenue.

trict is made up of 96.64 acres of roof area, or 43.5%, 103.32 acres of paved area, or 46.5%, and 21.76 acres of grass area, or about 10 per cent. The population was estimated at 37 700 persons. Rain gauges were placed on roofs in various parts of the district, and were read after each storm and compared with the self-registering gauge located more than 2 miles to the north in Central Park, from which the various rates of fall during each storm were taken. The results from the rain gauges were then plotted on cross-section paper, with time, in hours and minutes of the day as abscissas and the recorded intensities as ordinates. On this same sheet was plotted the rate of run-off, in cubic feet per second, as ordinates to agree with the recorded times of day as abscissas. Table 1 is a record of the complete series of observations."

The first part of Table 2 shows seven of the most severe storms of the year, with average rates. These storms, plotted as described above, are shown on Plate CXVIII. The wide range and sudden changes in intensity are in this way clearly shown, together with the corresponding flow in the sewer.

A study of Table 1 and the diagrams on Plate CXVIII shows that there is a wide variation in the rates of rainfall and in the percentage running off, and makes it evident that there is not much to be gained by considering the light rains, with the object of determining the maximum run-off.

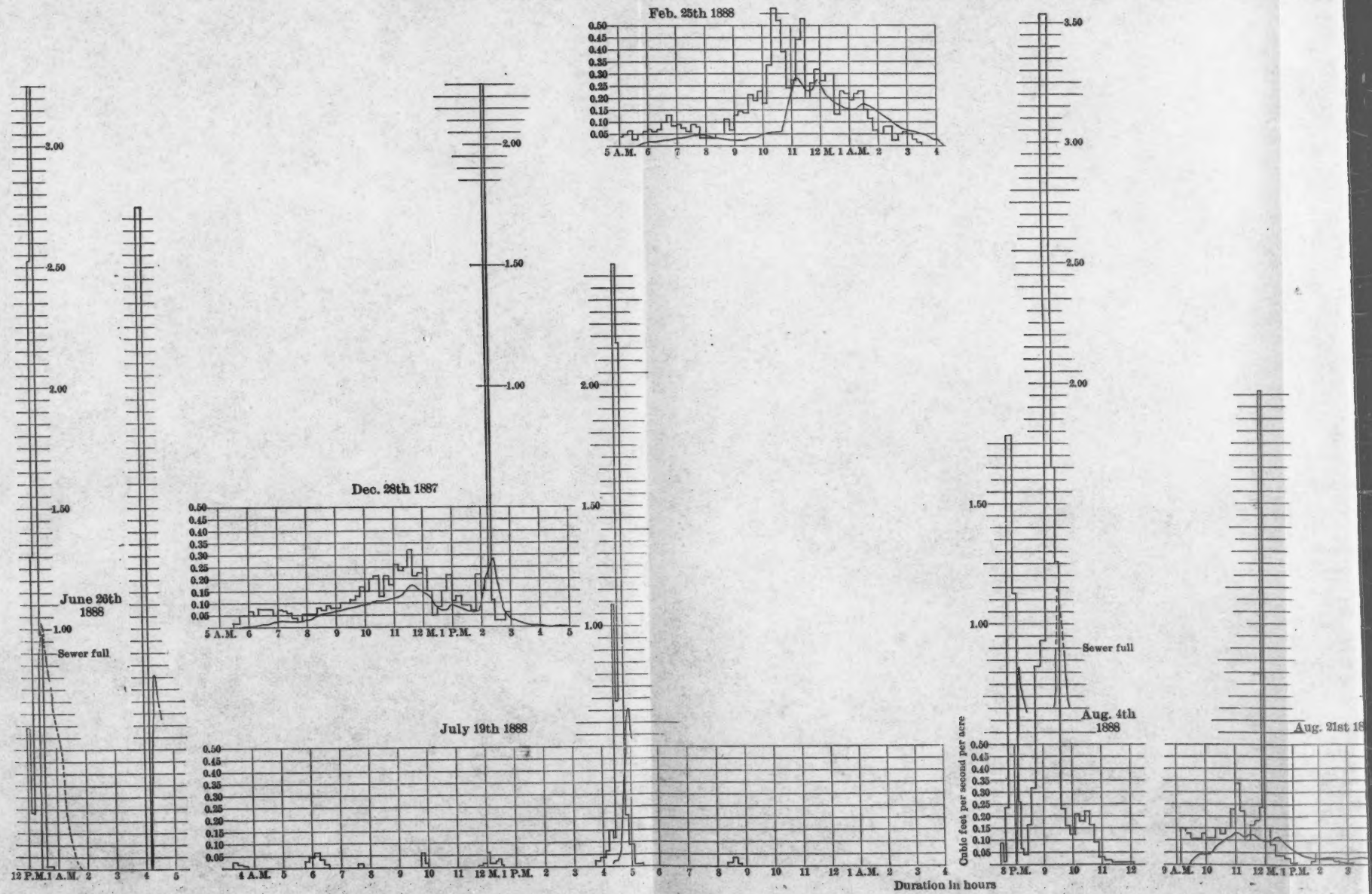
Mr. Hering, after comparing his results with the McMath data, concluded by recommending diagrams plotted for a formula like McMath's in form, but with slightly changed exponents, and constants. With the usual notation, this formula is:

$$Q = C\,R\,A^{0.83}\,S^{0.27},$$

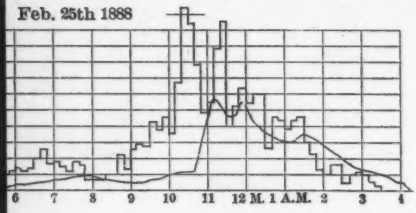
in which he recommends $CR = 1.64$ for metropolitan districts, and $CR = 1.02$ for suburban districts.

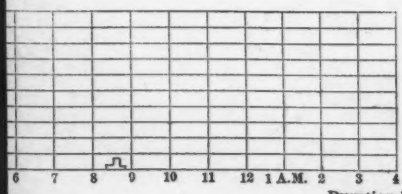
In 1900 two sewers were gauged by Mr. L. M. Hastings, City Engineer of Cambridge, Mass., and were mentioned by John R. Freeman, M. Am. Soc. C. E., in his report on the Charles River Improvement. The water-sheds of both sewers were small. The Sherman Street District contained 68 acres, with a slope of 32 ft. per 1 000, and 28% of impervious area, the remainder of the surface being nearly all grassland with steep slopes; the subsoil consisted of clay. The Shepard Street District contained 56 acres, with a slope of 28 ft. per 1 000, and 36% of impervious area. The soil was of a loose sandy nature, and the slopes were light. The

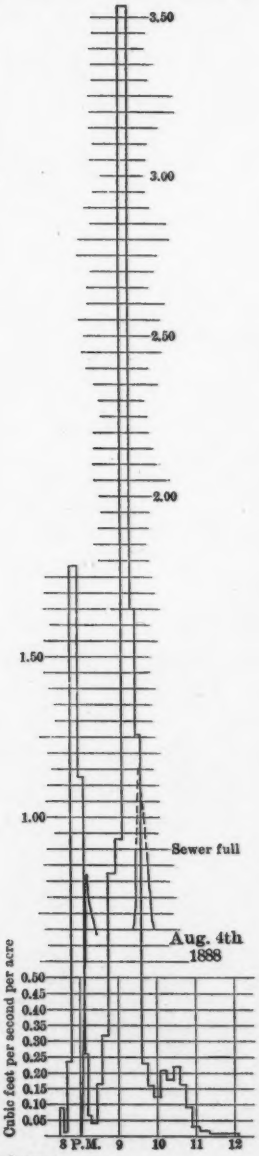
DIAGRAMS OF RAIN STORMS AND RUN-OFF IN SEWERS, SIXTH AVENUE DISTRICT, NEW YORK C

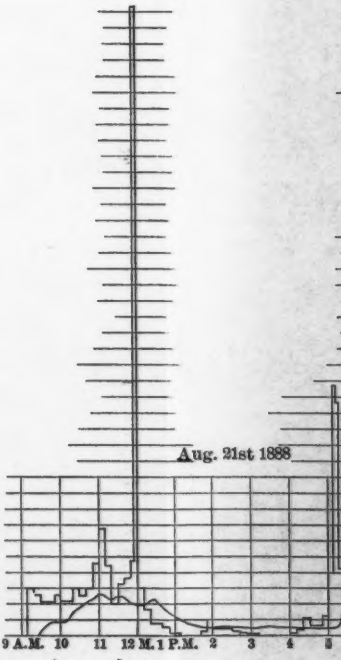


# STORMS AND RUN-OFF IN SEWERS, SIXTH AVENUE DISTRICT, NEW YORK CITY.



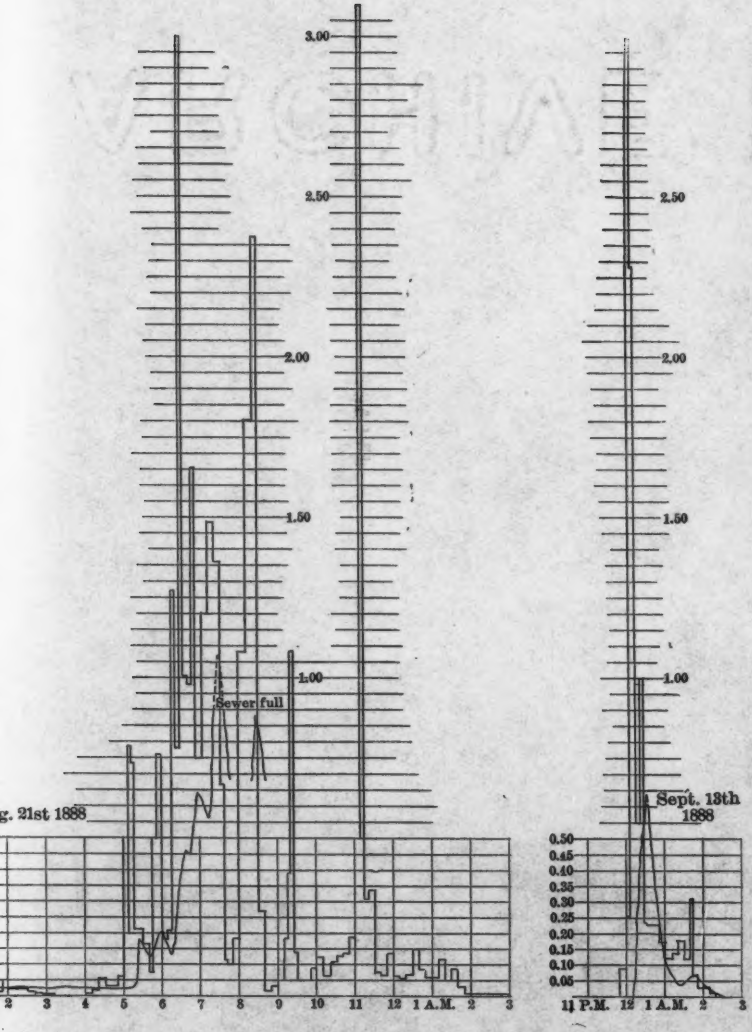




Duration in hours

RK CITY.


3.00
2.50
2.00
1.50
1.00
Sewer full
g. 21st 1888
2 3 4 5 6 7 8 9 10 11 12 1 A.M. 2 3


2.50
2.00
1.50
1.00
Sept. 13th
1888
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
11 P.M. 12 1 A.M. 2 3

most noticeable thing brought out was the great difference in the run-off from these two water-sheds, evidently due to the nature of the so-called pervious area. The maximum rate of run-off recorded was about 0.7 in. per hour for the Sherman Street, and 0.51 in. per hour for the Shepard Street water-shed, and both were caused by a sudden downpour which lasted only 8 min. While sufficient data are not given to calculate accurately the time required for the water to concentrate from these water-sheds, it was probably about 15 min. for each. The diagrams published by Mr. Freeman, while very complete for the purpose for which he used them, were drawn on too small a scale to enable one to estimate accurately the greatest average intensities for periods of 15 min. or less, as the unit of time seems to have been 1 hour, except for the storms of August 27th, when 0.6 in. fell in 8 min., and July 5th and August 10th, when 0.5 in. fell in 5 min. The storm of August 10th (Table 2) is difficult to explain when compared with that of August 27th, unless these sudden dashes of short duration were local, and very much less actually fell on the Sherman Street than on the Shepard Street water-shed, or where the rain gauge was located. The nearest rain gauge was about 1 mile from the area gauged.

The next greatest run-off was caused by a long storm, of varying intensities, on May 3d, in which about 2 in. of rain fell, and the greater part of this in 2 hours. The maximum run-off from this storm (Table 2) was 0.6 in.

In justification of the design of the Walworth sewer, and the proposed formula,

$$Q = A\,C\,R\sqrt[6]{\frac{S^{\frac{2}{3}}}{A}},$$

in which $C$ equals unity for impervious areas, W. C. Parmley, M. Am. Soc. C. E., gives the following experimental data:* "A sudden rain dash, not so severe as to cause more than passing remark, and not lasting more than 20 min., caused the 14 ft. 9-in. sewer to flow one-third full." This storm may have had an intensity of 2.5 in. per hour, and, therefore, from the 1 434 acres, may have reasonably caused a run-off equal to 640 cu. ft. per sec., about as observed, or it may not have done so. Information of this kind is of little value, and is apt to lead to erroneous conclusions.

* *Transactions*, Am. Soc. C. E., Vol. LV, p. 412.

TABLE 1.—Comparison of Rainfall, and Discharge from Area of which

From the Report on the Sewerage System of New York City,

| No. | Date. | Rain Data. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total fall. | Duration. | | Total rainfall, cubic feet per acre. | Maximum fall. | Duration, in minutes. | Rate per hour. | Cubic feet per second, per acre. |
| | | | Hours. | Minutes. | | | | | |
| 1 | Dec. 15th, 1887.. | 0.692 | 9 | 00 | 2 511.96 | 0.031 | 10 | 0.186 | 0.188 |
| 2 | " 28th, 1887.. | 1.170 | 10 | 45 | 4 247.10 | 0.149 | 4 | 2.235 | 2.253 |
| 3 | Jan. 25th, 1888.. | 0.830 | 9 | 30 | 3 012.90 | 0.097 | 10 | 0.582 | 0.587 |
| 4 | Feb. 7th, 1888.. | 0.250 | 5 | 40 | 907.50 | 0.021 | 3 | 0.420 | 0.423 |
| 5 | " 25th, 1888.. | 1.650 | 10 | 30 | 5 989.50 | 0.094 | 10 | 0.564 | 0.565 |
| 6 | Mar. 3d, 1888.. | 0.030 | 1 | 20 | 108.90 | 0.024 | 10 | 0.144 | 0.145 |
| 7 | " 11th, 1888.. | 2.090 | 27 | 05 | 7 586.70 | ..... | ..... | ..... | ..... |
| 8 | " 21st, 1888.. | 0.744 | 16 | 50 | 2 700.72 | 0.100 | 10 | 0.600 | 0.605 |
| 9 | " 27th, 1888.. | 0.190 | 2 | 20 | 689.70 | 0.044 | 10 | 0.264 | 0.266 |
| 10 | April 5th, 1888.. | 1.560 | 15 | 00 | 5 662.80 | 0.070 | 10 | 0.420 | 0.423 |
| 11 | " 14th, 1888.. | 0.110 | 6 | 50 | 399.30 | 0.019 | 5 | 0.228 | 0.230 |
| 12 | May 11th, 1888.. | 1.694 | 20 | 35 | 6 149.22 | 0.128 | 10 | 0.768 | 0.774 |
| 13 | " 14th, 1888.. | 0.680 | 22 | 45 | 2 468.40 | 0.049 | 5 | 0.588 | 0.593 |
| 14 | " 18th, 1888.. | 0.537 | 13 | 25 | 1 949.31 | 0.098 | 4 | 1.470 | 1.482 |
| 15 | " 24th, 1888.. | 0.371 | 13 | 00 | 1 346.73 | 0.029 | 10 | 0.174 | 0.175 |
| 16 | " 26th, 1888.. | 0.226 | 4 | 00 | 820.38 | 0.026 | 10 | 0.156 | 0.157 |
| 17 | June 15th, 1888.. | 0.301 | 2 | 00 | 1 092.63 | 0.076 | 8 | 0.570 | 0.575 |
| 18 | " 26th, 1888.. | 0.953<br>0.456 | 1<br>0 | 05<br>10 | 3 459.39<br>1 655.28 | 0.583 | 13 | 2 691 | 2.711 |
| 19 | " 28th, 1888.. | 1.768 | 27 | 23 | 6 417.84 | 0.118 | 4 | 1.770 | 1.784 |
| 20 | July 9th, 1888.. | 0.454 | 21 | 45 | 1 648.02 | 0.019 | 10 | 0.114 | 0.115 |
| 21 | " 19th, 1888.. | 0.650 | 24 | 20 | 2 359.05 | 0.394 | 10 | 2.364 | 2.384 |
| 22 | " 27th, 1888.. | 0.198 | 7 | 30 | 718.74 | 0.018 | 10 | 0.108 | 0.109 |
| 23 | Aug. 4th, 1888.. | 1.844 | 4 | 00 | 6 693.72 | 0.590 | 10 | 3.540 | 3.569 |
| 24 | " 12th, 1888.. | 0.420 | 3 | 45 | 1 524.60 | 0.079 | 10 | 0.474 | 0.478 |
| 25 | " 21st, 1888.. | 3.750 | 20 | 00 | 13 612.05 | 0.396 | 10 | 2.376 | 2.396 |
| 26 | Sept. 11th, 1888.. | 1.182 | 17 | 10 | 4 290.66 | 0.200 | 10 | 1.200 | 1.210 |
| 27 | " 13th, 1888.. | 0.873 | 2 | 25 | 3 168.99 | 0.299 | 7 | 2.563 | 2.583 |
| 28 | " 19th, 1888.. | 1.424 | 22 | 40 | 5 169.12 | 0.410 | 16 | 1.537 | 1.550 |
| 29 | Oct. 6th, 1888.. | 2.035 | 22 | 10 | 7 387.05 | 0.145 | 15 | 0.580 | 0.584 |
| 30 | " 12th, 1888.. | 0.204 | 6 | 30 | 740.52 | 0.024 | 10 | 0.144 | 0.144 |
| 31 | " 16th, 1888.. | 0.327 | 25 | 15 | 1 187.01 | 0.090 | 5 | 1.080 | 1.089 |
| 32 | " 19th, 1888.. | 0.395 | 20 | 35 | 1 433.85 | 0.088 | 10 | 0.528 | 0.528 |
| 33 | " 27th, 1888.. | 0.562 | 18 | 25 | 2 040.06 | 0 048 | 10 | 0.288 | 0.288 |
| 34 | " 28th, 1888.. | 0.132 | 2 | 05 | 479.16 | 0.020 | 10 | 0.120 | 0.120 |
| 35 | Nov. 8th, 1888.. | 1.832 | 49 | 00 | 6 661.05 | 0.187 | 5 | 2.244 | 2.263 |
| 36 | " 15th, 1888.. | 1.222 | 14 | 20 | 4 438.86 | 0.068 | 9 | 0.453 | 0.457 |
| 37 | " 19th, 1888.. | 0.496 | 14 | 10 | 1 800.48 | 0.037 | 10 | 0.222 | 0.222 |
| 38 | " 25th, 1888.. | 0.770 | 40 | 05 | 2 795.10 | 0.010 | 10 | 0.060 | 0.060 |
| 39 | Dec. 9th, 1888.. | 0.243 | 9 | 00 | 882.09 | 0.015 | 10 | 0.090 | 0.090 |
| 40 | " 11th, 1888.. | 0.302 | 4 | 33 | 1 096.26 | 0.020 | 10 | 0.120 | 0.120 |
| 41 | " 17th, 1888.. | 2.290 | 24 | 05 | 8 312.70 | 0.108 | 5 | 1.296 | 1.307 |
| 42 | " 27th, 1888.. | 0.405 | 18 | 22 | 1 470.15 | 0.050 | 4 | 0.750 | 0.756 |

THE SIXTH AVENUE SEWER, NEW YORK CITY, THE DRAINAGE IS 221 ACRES.

by Rudolph Hering, M. Am. Soc. C. E., May 31st, 1889.

| Flow Data. | | | | | Remarks. |
|---|---|---|---|---|---|
| Discharge of rain, in cubic feet per acre. | Percentage of rainfall reaching sewer. | Cubic feet per second for maximum flow. | | Percentage of maximum rainfall reaching sewer. | |
| | | Total. | Per acre. | | |
| 1 500.0 | 0.597 | 19.732 | 0.089 | 0.473 | |
| 2 892.0 | 0.681 | 64.296 | 0.290 | 0.129 | |
| 648.0 | 0.212 | 12.638 | 0.057 | 0 097 | 1½ in. of snow. |
| 324.0 | 0.357 | 10.864 | 0.049 | 0.116 | |
| 3 312.0 | 0.553 | 61.635 | 0.278 | 0.492 | |
| 4.2 | 0.089 | 0.665 | 0.003 | 0.021 | |
| ..... | ..... | ..... | ..... | ..... | Severe snow storm (blizzard). |
| 2 760.0 | 1.022 | 35.474 | 0.160 | 0.264 | |
| 267.6 | 0.388 | 18.624 | 0.084 | 0.314 | |
| 3 099.0 | 0.547 | 79.594 | 0.359 | 0.848 | |
| 276.0 | 0.691 | 19.067 | 0.086 | 0.374 | |
| 3 894.0 | 0.633 | 102.430 | 0.462 | 0.597 | |
| 1 419.0 | 0.575 | 60.305 | 0.272 | 0.458 | Two storms. |
| 1 272.0 | 0.653 | 121.275 | 0.547 | 0.368 | |
| 864.0 | 0.642 | 25.275 | 0.114 | 0.651 | Two storms. |
| 492.0 | 0.600 | 14.633 | 0.066 | 0.420 | |
| 450.0 | 0.412 | 41.460 | 0.187 | 0.325 | |
| 1 692.0 / 684.0 | 0.489 / 0.413 | 199.982 | 1.022 | 0.377 | Very heavy thunder showers. |
| 3 678.0 | 0.574 | 180.915 | 0.816 | 0.457 | Local storm. (Note.) The fall at our gauges much greater than at Professor Draper's. |
| 600.0 | 0.364 | 9.977 | 0.045 | 0.391 | |
| 878.5 | 0.372 | 147.659 | 0.663 | 0.279 | |
| 240.0 | 0.334 | 5.321 | 0.024 | 0.220 | |
| 5 157.0 | 0.770 | 199.982 | 1.162 | 0.326 | Storm of greatest intensity during year. |
| 540.0 | 0.354 | 22.836 | 0.103 | 0.216 | |
| 9 600.0 | 0.705 | 199.982 | 1.026 | 0.428 | |
| 981.0 | 0 229 | 138.791 | 0.626 | 0.517 | |
| 1 284.0 | 0.405 | 146.550 | 0.661 | 0.256 | |
| ..... | ..... | 157.414 | 0.710 | 0.458 | Sewer record not complete. Float caught. |
| 4 620.9 | 0.625 | 89.347 | 0.403 | 0.690 | |
| 555.6 | 0.750 | 17.298 | 0.078 | 0.542 | |
| 1 131.6 | 0.953 | 69.839 | 0.315 | 0.289 | |
| 903.6 | 0.630 | 58.753 | 0.265 | 0.502 | |
| 1 896.0 | 0.929 | 24.166 | 0.109 | 0.378 | |
| 276.0 | 0.576 | 10.420 | 0.047 | 0.392 | |
| 6 247.2 | 0.938 | 199.973 | 0.902 | 0.399 | |
| 3 680.0 | 0.830 | 76.263 | 0.344 | 0.753 | |
| 1 500.0 | 0.833 | 31.926 | 0.144 | 0.649 | |
| 2 683.2 | 0.960 | 12.415 | 0.056 | 0.983 | Snow and hail 1½ in. on 25th. |
| 759.0 | 0.860 | 9.311 | 0.042 | 0.467 | |
| 1 008.0 | 0.919 | 16.849 | 0.076 | 0.633 | |
| 5 756.0 | 0.692 | 107.746 | 0.486 | 0.372 | |
| 1 339.2 | 0.911 | 23.057 | 0.104 | 0.138 | |

## TABLE 2.—Short-Time Storms.

| (1) Location and designation of water-shed. | (2) Number of acres. | (3) Date of storm. | (4) Percentage of impervious area. | (5) Time of flow through longest line of sewer on water-shed, in minutes. | (6) Average rate of rain, in inches per hour, for time stated in Column 5. | (7) Observed maximum run-off rate, in cubic feet per second per acre. | (8) Ratio of run-off to rainfall, C. | (9) Remarks. |
|---|---|---|---|---|---|---|---|---|
| New York City—6th Ave. District..... | 221 | June 26, 1888 | 90 | 15 | 2.367 | 1.022 | 0.431 | |
| | 221 | July 19, 1888 | 90 | 15 | 1.850 | 0.666 | 0.360 | |
| | 221 | Aug. 4, 1888 | 90 | 15 | 2.910 | 1.162 | 0.399 | End of storm. |
| | 221 | Aug. 21, 1888 | 90 | 15 | 2.180 | 0.880 | 0.404 | Beginning of storm. |
| | 221 | " | 90 | 15 | 1.347 | 0.470 | 0.342 | End of storm. |
| | 221 | Sept. 13, 1888 | 90 | 15 | 1.570 | 0.661 | 0.421 | |
| | 221 | Dec. 28, 1887 | 90 | 15 | 0.730 | 0.290 | 0.390 | |
| | | | | | Average..... | | 0.391 | |
| Cambridge, Mass.—Shepard St. Dist... | 56 | July 25, 1900 | 36 | 5 | 4.8 | 0.33 | 0.070 | |
| | 56 | Aug. 10, 1900 | 36 | 5 | 5.4 | 0.36 | 0.066 | |
| | | | | | Average..... | | 0.07 | |
| Cambridge, Mass.—Sherman St. Dist.. | 68 | July 25, 1900 | 28 | 5 | 3.6 | 0.45 | 0.125 | From Cambridge gauge. |
| | 68 | Aug. 10, 1900 | 28 | 5 | 4.8 | 0.20 | 0.042* | " Harvard " |
| | | | | | Average..... | | 0.125 | |
| Rochester, N. Y.—District I..... | 357 | April 5, 1888 | 15 | 34 | 0.24 | 0.025 | 0.11 | |
| | 357 | May 26, 1888 | 15 | 34 | 0.57 | 0.086 | 0.15 | |
| | 357 | June 24, 1888 | 15 | 34 | 1.40 | 0.140 | 0.10 | |
| | 357 | June 24, 1888 | 15 | 34 | 1.55 | 0.165 | 0.105 | 2 hours later. |
| | 357 | July 11, 1888 | 15 | 34 | 0.41 | 0.056 | 0.14 | |
| | 357 | July 18, 1888 | 15 | 34 | 0.36 | 0.058 | 0.16 | |
| | 357 | Aug. 4, 1888 | 15 | 34 | 0.4 | 0.046 | 0.115 | |
| | 357 | Aug. 16, 1888 | 15 | 34 | 0.95 | 0.08 | 0.09 | |
| | 357 | Aug. 17, 1888 | 15 | 34 | 0.60 | 0 072 | 0.12 | |
| | 357 | Aug. 26, 1888 | 15 | 34 | 1.11 | 0.10 | 0.09 | |
| | | | | | Average..... | | 0.12 | |
| Rochester, N. Y.—District IV..... | 128.7 | June 24, 1888 | 30 | 18 | 2.62 | 0.55 | 0.21 | |
| | 128.7 | July 11, 1888 | 30 | 18 | 0.66 | 0.12 | 0.18 | |
| | 128.7 | July 18, 1888 | 30 | 18 | 0.5 | 0.09 | 0.18 | |
| | 128.7 | Aug. 4, 1888 | 30 | 18 | 0.73 | 0.098 | 0.134 | |
| | 128.7 | Aug. 16, 1888 | 30 | 18 | 1.41 | 0.21 | 0.15 | |
| | 128.7 | Aug. 26, 1888 | 30 | 18 | 2.02 | 0.31 | 0.15 | |
| | | | | | Average..... | | 0.166 | |
| Rochester, N. Y.—District X..... | 25.12 | July 18, 1888 | 50 | 10 | 0.75 | 0.19 | 0.25 | |
| | 25.12 | Aug. 17, 1888 | 50 | 10 | 1.33 | 0.25 | 0.19 | |
| | | | | | Average..... | | 0.22 | |
| Rochester, N. Y.—District IX..... | 133 | May 26, 1888 | 38 | 15 | 0.84 | 0.117 | 0.14 | |
| | 133 | June 24, 1888 | 38 | 15 | 2.62 | 0.31 | 0.12 | |
| | 133 | July 11, 1888 | 38 | 15 | 0.72 | 0.148 | 0.20 | |
| | 133 | July 18, 1888 | 38 | 15 | 0.544 | 0.077 | 0.14 | |
| | 133 | Aug. 4, 1888 | 38 | 15 | 0 8 | 0.137 | 0.17 | |
| | 133 | Aug. 16, 1888 | 38 | 15 | 1.6 | 0.31 | 0.19 | |
| | 133 | Aug. 17, 1888 | 38 | 15 | 0 95 | 0.12 | 0.13 | |
| | 133 | Aug. 26, 1888 | 38 | 15 | 2.23 | 0.31 | 0.14 | |
| | | | | | Average..... | | 0.16 | |
| Rochester N. Y.—District XVII..... | 92.3 | May 26, 1888 | 30 | 16 | 0.88 | 0.187 | 0.21 | |
| | 92.3 | June 24, 1888 | 30 | 16 | 2.62 | 0.34 | 0.13 | |
| | 92.3 | July 11, 1888 | 30 | 16 | 0.76 | 0.166 | 0.22 | |
| | 92.3 | July 18, 1888 | 30 | 16 | 0.57 | 0.111 | 0.19 | |
| | 92.3 | Aug. 4, 1888 | 30 | 16 | 0.83 | 0.15 | 0.18 | |
| | 92.3 | Aug. 16, 1888 | 30 | 16 | 1.616 | 0.288 | 0.18 | |
| | 92.3 | Aug. 17, 1888 | 30 | 16 | 0.99 | 0.16 | 0.16 | |
| | 92.3 | Aug. 26, 1888 | 30 | 16 | 2.34 | 0.34 | 0.15 | |
| | | | | | Average..... | | 0.17 | |

* Too small; throw-out.

The results of the foregoing experiments are collected in Tables 2 and 3 for comparison and study. Table 2 contains data relating to storms of great intensity, but only of sufficient duration to allow all parts of the water-shed to contribute to the flow at the gauge. Table 3 contains data relating to longer storms, Column 8 indicating the length of the continuous rainfalls, and Column 10 giving the value of $C$ if the pervious area is considered to have no run-off.

A short statement and summary of some of the doubtful points in each set of experiments will be made, in order to give a correct idea of their relative importance.

The writer knows of no detailed account of the experiments on which Hawksley based his formula, but the general acceptance of his conclusions must have been due to the knowledge his contemporaries had of the experiments, or to confidence in the ability of their author. Later experience has shown that he erred more in his assumptions of the rainfall than in its relation to run-off.

The Bürkli-Ziegler was an adaptation of Hawksley's formula, but with better determined coefficients.

The McMath experiments were made in a very rough general way, and were really only a compilation of casual observations. They can be used only as a rough empirical check on similar conditions.

Mr. Kuichling's Rochester experiments, however, were made in a scientific manner, but lacked the precision that automatic gauges give to such work. Although the flow in the sewers was measured by pairs of gauges, placed so as to determine the slope of the water surface, the value in each case was impaired because they did not give the time of maximum for each, and, consequently, it is not known that the two summits occurred simultaneously. All details, however, were carefully worked out, and all conditions fully stated. Where sewers ran under a head, they were given credit for only their capacity when running full, which may or may not have been correct.

Mr. Hering's gaugings of the Sixth Avenue sewer, in New York City, were made with a single clock gauge, which recorded the depth of flow in the sewer; the water surface slopes, therefore, had to be assumed. Mr. Hering states in his report that conditions were suitable for the safe application of a slope formula, and it may

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rochester, N. Y.—District I. | 357 | Dec. 10, 1888 | 15 | 34 | 0.31 | 60 | 0.043 | 0.14 | | |
| | 357 | May 9, 1888 | 15 | 34 | 0.93 | 70 | 0.21 | 0.22 | | |
| | 357 | June 28, 1888 | 15 | 34 | 0.46 | 105 | 0.14 | 0.30 | | |
| | 357 | Sept. 16, 1888 | 15 | 34 | 0.47 | 50 | 0.093 | 0.20 | | |
| Rochester, N. Y.—District IV. | 128.7 | May 10, 1888 | 30 | 18 | 0.31 | 60 | 0.072 | 0.23 | | |
| | 128.7 | June 28, 1888 | 30 | 18 | 0.45 | 105 | 0.23 | 0.51 | | |
| | 128.7 | Sept. 16, 1888 | 30 | 18 | 0.47 | 50 | 0.18 | 0.40 | | |
| | 128.7 | May 9, 1888 | 30 | 18 | 0.77 | 35 | 0.26 | 0.33 | | |
| Rochester, N. Y.—District X. | 25.12 | May 26, 1888 | 50 | 10 | 1.00 | 13 | 0.32 | 0.32 | | |
| | 25.12 | Aug. 16, 1888 | 50 | 10 | 1.62 | 15 | 0.40 | 0.25 | | |
| | 25.12 | Aug. 26, 1888 | 50 | 10 | 2.5 | 14 | 0.84 | 0.34 | | |
| | 25.12 | June 24, 1888 | .... | ..... | 2.62 | 20 | 0.85 | 0.32 | | |
| | 25.12 | June 28, 1888 | .... | ..... | 0.8 | 20 | 0.29 | 0.36 | This summit may have been the result of the longer rain. | |
| | 25.12 | Dec. 10, 1888 | .... | ..... | 0.31 | 60 | 0.18 | 0.6 | | |
| | 25.12 | June 28, 1888 | .... | ..... | 0.45 | 105 | 0.29 | 0.8 | This summit may have been the result of the shorter rain. | |
| Rochester, N. Y.—District IX. | 133 | Dec. 10, 1888 | .... | ..... | 0.31 | 60 | 1.28 | 0.41 | | |
| | 133 | Jan. 28, 1888 | ... | ..... | 0.45 | 105 | 0.28 | 0.62 | | |
| Rochester, N. Y.—District XVII. | 92.3 | Dec. 10, 1888 | .... | ..... | 0.31 | .... | 0.08 | 0.26 | | |
| | 92.3 | June 28, 1888 | .... | ..... | 0.45 | .... | 0.30 | 0.66 | | |
| Hartford, Conn.—Franklin Ave. Sewer. | 280 | July 11, 1900 | 45 | 17 | 3.4 | 17 | 0.34 | 0.10 | 0.40 | |

TABLE 3.—LONG-TIME STORMS.

| (1) Location and designation of water-shed. | (2) Number of acres. | (3) Date of storm. | (4) Percentage of impervious area. | (5) Time of flow through longest line of sewer on water-shed, in minutes. | (6) Equivalent uniform rate, for duration of rain considered. | (7) Duration of continuous rain, in minutes. | (8) Rate of run-off at end of continuous rain. | (9) $C$, as observed. | (10) $C$, if pervious area has no run-off. | (11) Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| New York City.—6th Ave. District. | 221 | Aug. 21, 1888 | 90 | 15 | 1.36 | 15 | 0.47 | 0.35 | 0.39 | |
| | 221 | " | 90 | 15 | 1.20 | 30 | 0.65 | 0.54 | 0.60 | 1.40 rate for last 15 min. |
| | 221 | " | 90 | 15 | 1.07 | 73 | 0.90 (reduced) | .... 0.84 | .... 0.93 | 1.07 rate for preceding 25 min.<br>0.33 rate × 0.39 = 0.13.<br>1.03 − 0.13 = 0.90 reduced rate. |
| | 221 | Feb. 25, 1888 | 90 | 15 | 0.49 | 30 | 0.28 | 0.57 | 0.63 | |
| | 221 | " | 90 | 15 | 0.36 | 68 | 0.27 | 0.75 | 0.83 | Average for last 38 min. immediately preceding summit = 0.36. |
| | 221 | Dec. 28, 1887 (short) | 90 | 15 | 0.73 | 15 | 0.29 | 0.39 | 0.43 | |
| | 221 | Dec. 28, 1887 | 90 | 15 | 0.25 | 60 | 0.18 | 0.72 | 0.80 | |
| Cambridge, Mass.—Shepard St. District. | 56 | May 3, 1900 | 36 | 5 | 0.50 | 30 | 0.13 | 0.26 | 0.72 | |
| | 56 | " | 36 | 5 | 0.38 | 70 | 0.13 | 0.34 | 0.95 | |
| | 56 | Sept. 18, 1900 | 36 | 5 | 0.4 | 30 | 0.10 | 0.25 | 0.70 | |
| | 56 | " | 36 | 5 | 0.54 | 80 | 0.14 | 0.26 | 0.72 | |
| | 56 | " | 36 | 5 | 0.48 | 150 | 0.17 | 0.35 | 0.98 | Average for last 50 min. immediately preceding summit = 0.48. |
| Cambridge, Mass.—Sherman St. District. | 68 | Sept. 18, 1900 | 28 | 5 | 0.58 | 30 | 0.20 | 0.34 | Averages of gauges at Harvard and Cambridge. | |
| | 68 | " | 28 | 5 | 0.52 | 60 | 0.32 | 0.62 | " " " " " " " | |
| | 68 | " | 28 | 5 | 0.70 | 120 | 0.61 | 0.87 | " " " " " " " | for last 30 min. |
| | 68 | May 3, 1900 | 28 | 5 | 0.43 | 60 | 0.23 | 0.53 | Averages of gauges at Harvard and Cambridge. | |
| | 68 | " | 28 | 5 | 0.38 | 90 | 0.25 | 0.66 | " " " " " " " | |
| | 68 | " | 28 | 5 | 0.55 | 120 | 0.44 | 0.80 | " " " " " " " | for last 60 min. |

be only a matter of opinion whether or not this was true. The most serious objection is that the automatic gauge from which the rainfall rates were obtained was 2 miles distant, in Central Park, and these rates were checked with the rain gauges on the area, for total amounts only.

The experiments made by Mr. M. L. Hastings, seem to have only one serious fault, and that is that there were no rain gauges on the areas, the rain rates being taken from two gauges widely separated, the nearest one being about a mile away. Between these gauges there was often a difference of 50%, and, consequently, a possible error of that much in the quantity of rain falling on the areas. The flow in the sewers was measured by pairs of gauges 600 ft. apart, in order to determine the water surface slopes, but the distance was so great that there might have been changes in the slope between the stations, and, consequently, inaccurate results.

A single gauging of a very severe thunderstorm in Hartford, Conn., by F. L. Ford, M. Am. Soc. C. E., is typical of the storms of great intensity in New England, and is the only one given in detail in his report. Two spring freshet storms are recorded, but as it is so evident that the run-off was influenced to a very great extent by the condition of the sewer outlet, or by other unknown local complications, they are considered of little or no value in deducing general laws. There were automatic rain gauges on three sides of the area gauged, two of them on the outskirts of the water-shed, and the other about ½ mile away, at the City Hall, and the flow in the sewer was measured by two clock gauges about 3 000 ft. apart. In this observation the greatest lack is accurate knowledge of the characteristics of the water-shed, such as the total area actually tributary, the percentage of impervious area, etc.

Since making some of the investigations reported above, a few general laws have been quite generally accepted. Their acceptance, probably, is due quite as much to their broad reasonableness as to experimental determination. They may be stated as follows:

The quantity of run-off from any catchment area is a function (1st) of its area; (2d) of the rate of rainfall; (3d) of the slope; (4th) of the percentage of impervious area; and (5th) depending on the shape of the water-shed. It has been expressed by Messrs. E. Kuichling, A. N. Talbot, and others, in the following general

form: $Q = A\,C\,i$, in which $Q$ is the run-off, in cubic feet per second; $C$ is a coefficient, supposed to be a constant, expressing the relation between run-off and rainfall on a particular water-shed, and a function of impervious area; $i$ is the intensity or rate of rainfall, in inches per hour, lasting a sufficient time to cause all parts of the area to contribute to the flood wave at a given point at the same time, and, therefore, is a function of the slope and length of the water-shed; and $A$ is the number of acres drained.

For comparison with each other, and with the two formulas proposed by the writer, the exponential formulas most extensively used have been reduced to the same form and notation as follows:

Hawksley ..... $Q = A\,C\,R\sqrt[4]{\frac{S}{A}}$, { in which $C = 0.7$, $R = 1$ to 2

Bürkli-Ziegler ..... $Q = A\,C\,R\sqrt[4]{\frac{S}{A}}$ { in which $C = 0.7$ to 0.9, $R = 1$ to 3

McMath ..... $Q = A\,C\,R\sqrt[5]{\frac{S}{A}}$ { in which $C = 0.1$ to 0.8, $R = 1$ to 2.75

New York diagrams.. $Q = A\,C\,R\sqrt[6]{\frac{S^{1.62}}{A}}$ { in which $CR = 1.62$ to 1.05

Parmley ..... $Q = A\,C\,R\sqrt[6]{\frac{S^{\frac{3}{2}}}{A}}$ { in which $C = 0$ to 1, $R = 4$

Adams..... $Q = A\,C\,R\sqrt[6]{\frac{S^{\frac{1}{2}}}{A\,R}}$ { in which $C = 1.837$, $R = 1$

Proposed ..... $Q = 2.8\,A\,\frac{S^{0.186}}{A^{0.14}}$ { for impervious surfaces.

Proposed ..... $Q = C\frac{105}{84\sqrt[5]{A\,S^2} + 25}$, { in which $C = 0.10$ to 0.54

The establishment of automatic rain gauges has made it possible to obtain rainfall intensities for all parts of a storm. From time to time various curves have been deduced to show the relation between rain intensities and duration. These curves are generally drawn from plottings of the rates of rain, in inches per hour, as ordinates, and the time, in minutes, as abscissas, by inclosing the points thus plotted. This curve usually takes the form of the hyperbola. The curves by A. N. Talbot, M. Am. Soc. C. E., for the

Eastern United States, Fig. 1, seem to have been most generally adopted for both ordinary and maximum rainfall.

Each locality, however, may have, and many have been shown to have, a somewhat different curve, as is shown by the diagram,

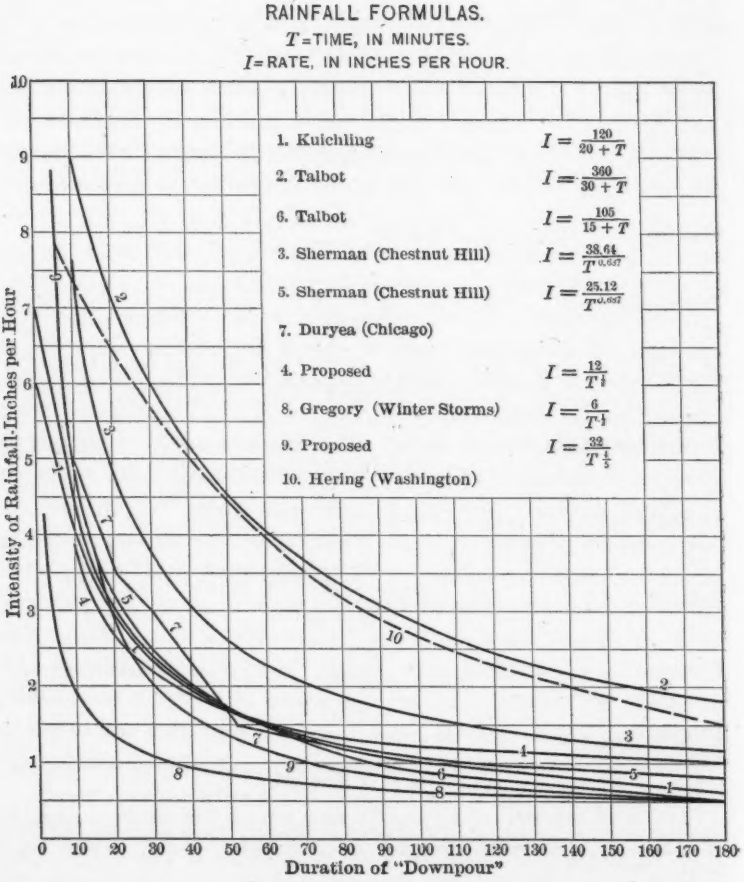



FIG. 1.

Fig. 1, on which are drawn curves deduced by competent authorities for different localities. These curves show the necessity for a solution of this problem which will give the relation between any rainfall curve and the consequent run-off, rather than an empirical

formula which gives the same result for different localities, regardless of the rain curve.

Curve 9 is proposed in order to obtain results for long-time rains which will be more like Talbot's ordinary curve, as it is the writer's opinion that curves based on the records of a single gauge give results which are too great for the average over large areas, and, consequently, too great for long-time storms.

The diagram, Fig. 10, shows a curve for rainfall during the winter, and includes all but two storms which have occurred between November 1st and April 1st, which have been reported as severe at the places indicated, covering long periods of time. This curve has values which are just half of those given by the proposed curve, $i = \frac{12}{t^{\frac{1}{2}}}$, for ordinary severe rainfalls for the entire year.

Having tabulated and briefly discussed the better known data relating to this problem, and very briefly reviewed the practice for the past fifty years, an attempt will be made to analyze these data and, as far as possible, harmonize them into a rational, workable method of design, applicable to all conditions and places, and to do it so that, not only maximum conditions may be predicted, but that, given any storm of more than moderate intensity, and the factors of the water-shed, the run-off can be estimated with a precision corresponding with the accuracy of the information given.

The almost universal failure of the inch-per-hour formulas and designs is easily explained by the now well-established fact that the rate of 1 in. per hour is quite often exceeded, and especially for water-sheds requiring but a short time for water to flow from the most remote part to the outlet, called short-time water-sheds. The other conclusions and data may be made to harmonize to as great an extent as their accuracy warrants, if rationally treated, even, perhaps, to reconciling Hawksley's 54% with W. C. Parmley's 100% run-off.

Even a very casual study of the data in Tables 2 and 3, and the methods of experiment, would suggest the need of further and more reliable experimental data, as each set of experiments has its own peculiar factors which are open to doubt, and also for the reason that there have been no long-time or very short-time water-sheds gauged.

The first part of Table 2 shows seven storms in the Sixth Avenue sewer district, in New York City. The percentage of run-off in each storm varies only 5% from the average of 39% of the average rainfall for 15 min. (the time required for the water to flow from the most remote part of the water-shed); or from 50% if this time be taken as 25 min. This, it may be noted, might explain and agree with the 54% run-off reported by Hawksley. The variation of 5% may be explained by inaccuracy in measuring the rainfall, as only one automatic gauge was used, and the average rate on the water-shed might easily vary that much, but would tend to equalize in the series. The condition of the 10% of pervious or grass area might also vary the result slightly, but the 90% of impervious area should give a constant ratio between actual rainfall and run-off, as it apparently does.

The Shepard Street district, in Cambridge, Mass., gives for two short intense storms (if judgment is exercised in determining the actual rate of rain on the water-shed) a very uniform ratio of 0.07 for 36% of impervious area. The Sherman Street district gives a ratio of 0.125 for 28% of impervious area, showing that the so-called pervious areas on each are of very different natures. This is borne out by the facts of the case, the Shepard Street district having flat slopes and sandy subsoil, while the Sherman Street district has steep slopes and a clay subsoil.

Following this there are several storms from Mr. Kuichling's Rochester gaugings, designated by districts. Here the pervious areas seem to be more uniform, and the run-off ratio follows the percentage of impervious areas more closely. The average value for $C$ for each district is deduced as designated.

It is reasonable to assume that all impervious areas, under similar conditions, should give a constant ratio for all storms of equal duration and intensity. In practice, however, all water-sheds and all rain storms are different; therefore, all storms and all water-sheds must be reduced to a common basis of comparison. The maximum flow from any water-shed, except one of unusual shape, obviously is at the time when all parts of the area are contributing their average maximum at the point of observation. For any shorter period only part of the area is contributing, and for a longer period the intensity of the rain is less. The average maximum

run-off occurs, obviously, and as is shown later, a few minutes after the time required for concentration. The exceptions to this general law are either when the shape or state of development of the water-shed are such that the increment from the farthest points is less than the corresponding decrease in intensity; and, for very short-time water-sheds, where the decrease in intensity is less than the corresponding increase in the value of $C$. This time required for concentration is not, as has often been stated, the total time elapsed between the beginning of the rain and the time of observed maximum run-off, but rather is the time elapsed while the water is traveling through the sewer from the most remote part, plus the time required for the water to reach the sewer from the roofs, pavements, and gutters, at the remote points, minus the time required to reach the sewer from near-by roofs, etc., as water that has not yet reached the sewer obviously cannot influence the maximum which occurs at that time. This is shown clearly on the diagrams of the Sixth Avenue sewer, where the maximum run-off occurs usually after the intense rain has ceased. This latter time will perhaps usually be about the same as the time at the most remote parts, and, consequently, where there is not known to be a difference, the time of concentration may be taken as the time that the water is in the sewer and passing from the most remote point to the gauge. Taken in this way, the time of concentration in the Sixth Avenue sewer was 15 min., and the ratios for each storm are shown in Table 2 to average 0.391. Each set of experiments is shown in the same way, and the average ratio is stated for the time of the water-shed.

Table 3 contains records of storms of long duration and of fairly uniform intensity. These storms, while not of very great intensity, caused a run-off nearly as great as many shorter storms of much greater intensity. A typical long-time severe rain, which occurred on August 21st, 1888, in the Sixth Avenue district, is shown on Plate CXVIII. This storm and also those of February 25th, 1888, and December 28th, 1887, are shown by the diagram, Fig. 8, on which is plotted the time, in minutes, as abscissas and the ratios of run-off to rainfall as ordinates; the different summits of the flow in the sewer are taken and the extreme rain rates above the average are reduced by giving them the same ratio as the short-

time rains and deducting the result from the total run-off before determining the ratio equivalent to a uniform rain. These ratios show a very regular increase. Each point is connected on the diagram by a broken line. If the 10% pervious areas, being small, be counted as 0, then the ratios for impervious surface will be indicated by the solid lines, as shown. In the same manner, on Fig. 8, are shown three storms in the Shepard Street district, Cambridge, Mass. Here, the pervious areas, although a much greater proportion of the total, seem to have absorbed the rain as rapidly as it fell; therefore these areas may also be made equal to 0, and this gives the points representing the ratio for impervious areas.

The severe storm at Hartford, Conn., is treated in a similar manner. The pervious areas are not as easily eliminated on the other water-sheds, and they will be analyzed by applying the apparent relations of the four storms just described. The ratio of run-off on both impervious and pervious areas for the different localities and times where the maximum occurred immediately following the intense rain, may be found by assuming that the ratio of run-off for similar times is the same on each, and selecting areas on which the pervious portions are similar in nature but different in relative extent, as follows: District IV, Rochester, N. Y., has 30% impervious area, and the Sixth Avenue district, New York, has 90% impervious area; let $x$ = ratio for impervious area and $y$ = ratio for pervious area:

then $$0.90\,x + 0.10\,y = 0.39$$

and $$0.30\,x + 0.70\,y = 0.166$$

eliminating $y$,

$$x = 0.42.$$

In this way it will be found that, wherever the pervious areas are similar, there is a remarkable uniformity in the values of $C$ for impervious areas. These values, and the proposed curves for the long-time storms just mentioned, both point to the fact that the ratio, $C$, is not a function of the impervious area alone, but has a wide range of values between 0 and 1.00 for totally impervious areas. They also show that the variation is not uniform, and that it is different for storms having a greater duration than the time required for concentration, although the actual time may be the same; that the ratio increases very rapidly during the first minutes

## DIAGRAMS SHOWING RELATION OF LONG-TIME UNIFORM STORMS TO PROPOSED CURVES, FOR FIVE DISTRICTS IN ROCHESTER, N.Y. AND FOR THE SHERMAN ST. DISTRICT IN CAMBRIDGE, MASS.

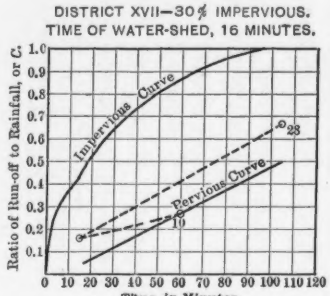



FIG. 2.

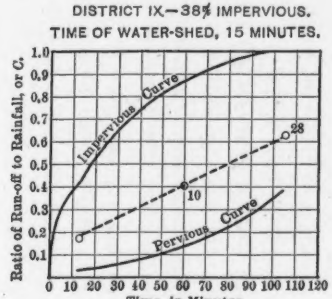



FIG. 3.

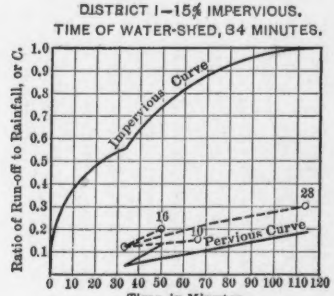



FIG. 4.

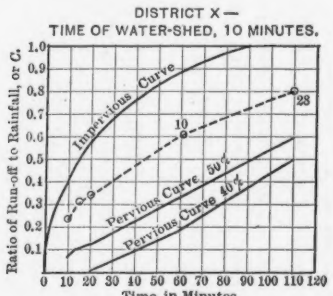



FIG. 5.

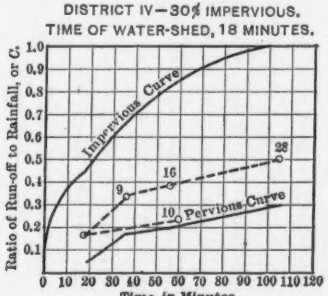



FIG. 6.

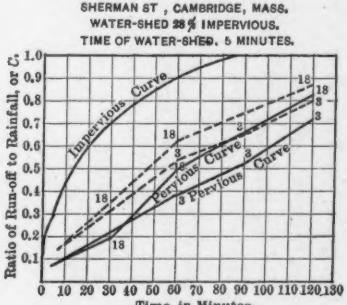



FIG. 7.

of a storm and then more gradually. The ratio for the time for concentration is necessarily less than the ratio for a greater time, because at this time part of the area is contributing the rain from the first minutes of the storm with a consequent small ratio. This relation was first roughly shown by the straight-line curves in Mr. Kuichling's paper.

This change in the ratio as the rain continues is due to many causes, among which is capillary action for small depths, and the inertia of the water. It is readily observed that, during very intense precipitations on surfaces slightly inclined, considerable depth is attained before the run-off equals the rainfall. This same phenomenon is true throughout, to a greater or less extent. In order to approximate the curve of the changing ratio for impervious area, it must be remembered that (for a unit of area) each actual observed ratio is an average of all ratios during the time required for concentration on the water-shed. Not yet knowing the law of change, assume that the rate of change is uniform for the time of the water-shed; then these average ratios will be points on the curve at a time that is less by one-half of the time for concentration than the time of the observed ratio. For illustration, take the last summit for the storm of August 21st, 1888, on the Sixth Avenue territory; the ratio for 73 min. is 0.84, and if the 10% pervious area is considered as equal to 0, the impervious area has a ratio of 0.93; this 0.93 is not plotted for 73 min. directly above the 0.84, but at 65½ min., which is 7½ min. (or one-half of the 15 min.) less than 73 min. Each point is treated in this way, and some of the averages for the time of the water-shed from Table 2 are also plotted in a similar manner.

After considerable study, the cubic parabola, $C = 0.233\, t^{\frac{1}{3}}$, was found to enclose these points and therefore express the rate of change of the value of $C$ for an elementary area. The ordinates of this curve give the ratios for each succeeding increment of $t$, and therefore the average ordinate for any time, $t$, is the area between the axis and the curve, $\frac{3}{4}\ (t\ C)$ divided by $t$, or $\frac{3}{4}$ of $C = \frac{3}{4}\ (0.233\ t^{\frac{1}{3}})$ $= 0.175\ t^{\frac{1}{3}}$. These curves are shown on the diagram, Fig. 8. The value of $C$, in the curve, $C = 0.233\ t^{\frac{1}{3}}$, becomes unity when $t =$ 80, or, in other words, it is proposed that where rain has fallen for

80 min. continuously on a unit of impervious area, the run-off has become equal to the rain, and, therefore, for all areas of greater time than 80 min. the average run-off must be expressed as follows:

$$\frac{(80 \times 0.75) + (t - 80)\,1}{t} = \frac{t - 20}{t},$$

a curve with an asymptote to $C$ = unity, or, in other words, the value of $C$ can never quite reach unity for a rain lasting only the time of the water-shed, however long the time.

PROPOSED CURVE SHOWING RATIO OF RAINFALL TO RUN-OFF FOR A UNIT AREA.

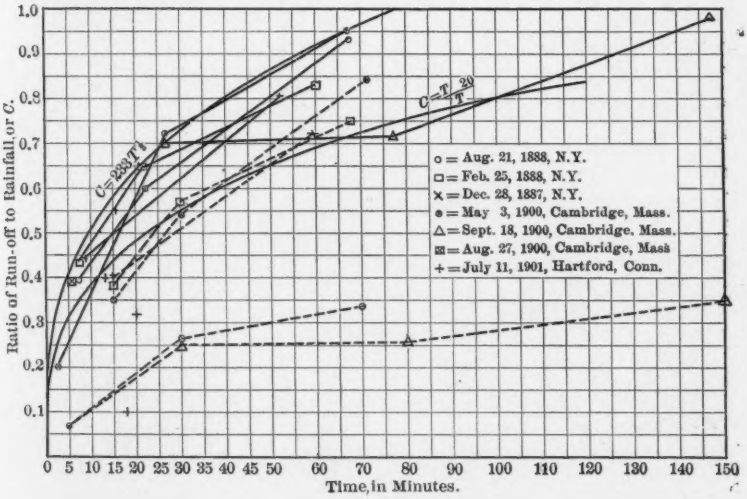



FIG. 8.

To show the general application of this method of analysis, all the storms in Table 3 not used to deduce the relation may be tested as follows:

On the diagram, Fig. 7, are plotted the storms on the Sherman Street district, Cambridge, the first point being the average of the storms for the time of the water-shed, and the other points being summits for the times indicated, those of September 18th being designated by 18, and those of May 3d by 3. These points are joined by broken lines. Then, from the curve for impervious areas, Fig. 8, values for $C$ are taken, as follows: For the time of the water-shed, say 5 min., the value of $C$ for the $\frac{3}{4}$-curve is 0.2. This

is plotted as the first point in the impervious curve. Next take, say, 10 min., then the rain has continued on the most remote part for 5 min., and on the nearest for 10 min., and the average ordinate or value for $C$ is $0.175 \frac{(10^{\frac{4}{3}} - 5^{\frac{4}{3}})}{5} = 0.47$. Continue in this manner until a sufficient number of points on the curve are located. These values for impervious areas are then applied to the 28% of impervious area on this water-shed, and the result is deducted from the observed ratio, the remainder being the run-off from the so-called pervious area; divide this by the percentage of pervious area, 0.62, and it becomes the ratio for this particular pervious area and duration. These points are joined to show the increase in the ratio as the ground becomes saturated. The diagrams, Figs. 2, 3, 4, 5 and 6, show storms of similar character on sewerage districts in Rochester, N. Y., from Mr. Kuichling's gaugings.

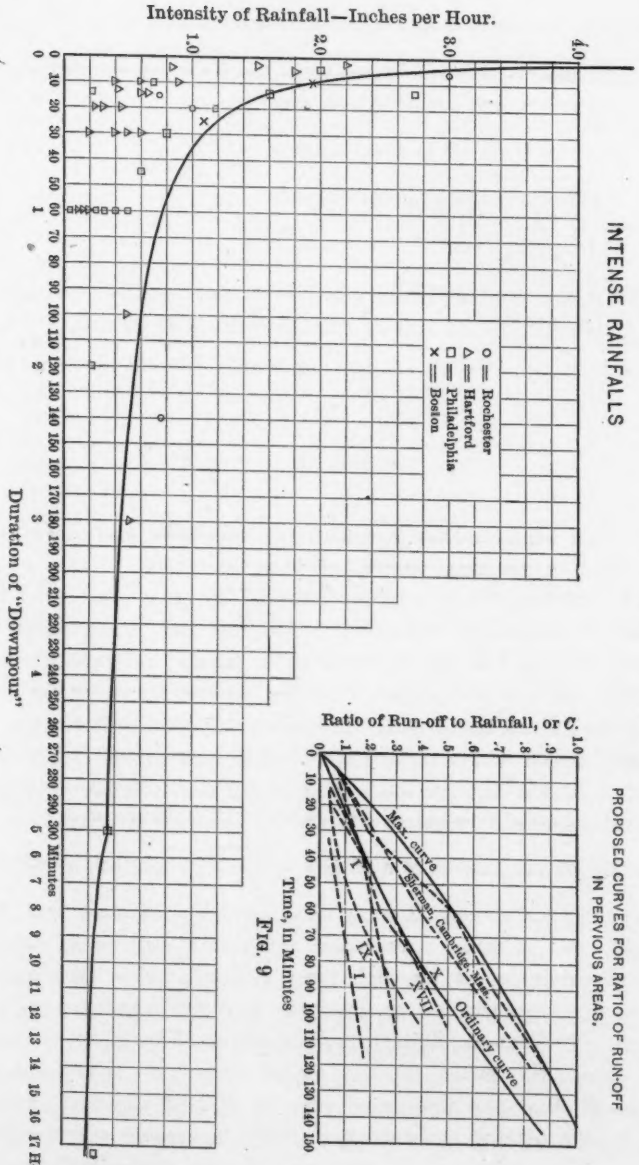
These pervious curves show that, under favorable circumstances, where grass areas have steep slopes and clay subsoil, rains having a duration of 90 min. may cause a rate of run-off nearly 90% as great as the rate of rain for that period; and, also, that, under conditions favorable for the absorption of the rain, the run-off may be practically zero.

The pervious curve from each diagram is then plotted on the diagram, Fig. 9, and two curves are drawn, one maximum to enclose all, and another ordinary to cover all the Rochester storms. The purpose of this diagram is to aid the judgment in estimating the run-off from pervious or grass areas, during the summer. The values lie probably anywhere between the maximum curve and zero.

Having now determined the law of change for $C$, the rational method of solution for any given case is as follows:

Calling cubic feet per second per acre equivalent to inches per hour, the run-off, in cubic feet per second, must equal the area in acres multiplied by $C$, determined from the diagram, Fig. 8, for the time of the water-shed, $t$, or the time of the duration of the rain, $T$, multiplied by the rate of rain for the time, or $Q = A\ C\ i$, in which, for impervious areas, $C = 0.175\ t^{\frac{1}{3}}$ for a storm of duration equal to the time for concentration, or, if for greater duration,

$$C = \frac{0.175}{t}\left(T^{\frac{4}{3}} - (T - t)^{\frac{4}{3}}\right),$$




INTENSE RAINFALLS

FIG. 10




PROPOSED CURVES FOR RATIO OF RUN-OFF IN PERVIOUS AREAS.

FIG. 9

and $i$, the intensity from any rainfall curve, as, say, $\frac{120}{T+20}$. The simplest case is where $T$ is equal to the time for concentration, $t$. Substitute for $C$ and $i$ their values, and

$$Q = A\ 0.175\ t^{\frac{1}{3}} \times \frac{120}{t+20},$$

then, for the maximum rate of run-off,

$$\frac{Q}{A} = \frac{19.8\ t^{\frac{1}{3}}}{t+20}.$$

Place the first derivative equal to 0, and $t = 10$, the time for the maximum rate of run-off for this particular rainfall curve.

If, however, $i = \frac{12}{t^{\frac{1}{2}}}$, or any exponential formula of similar form, then

$$Q = \frac{A\ \ 2.19\ t^{\frac{1}{3}}}{t^{\frac{1}{2}}} = \frac{2.19\ A}{t^{\frac{1}{6}}},$$

a function which always decreases as $t$ increases, and there are no maximum or minimum points, except at the limits.

The solution for a maximum run-off for any rain curve is as follows: It is evident from Fig. 8 that the ratio, $C$, increases very rapidly during the first minutes of a storm, and probably more rapidly than the rate of rain decreases, as was shown by the maximum run-off rate at 10 min. Therefore, it is easily shown that the greatest run-off will occur at some time between 10 min. and 0 after the time of flow through the longest line of sewer on the water-shed, this value being 10 when $t = 1$, and 0 when $t = 0$. Fig. 11 shows the curve of the rate of run-off if $i = \frac{120}{t+20}$ for water-sheds on which the time of flow through the longest line of sewer is 5 min., 30 min., and 70 min. From these and similar curves the locus of each maximum point for each time is plotted, with the times required for concentration as abscissas, and the maximum rates of run-off as ordinates. This curve is shown on Fig. 11 by a concave line. From this curve, the time being known, the maximum rate of run-off from any water-shed may be read off directly. Beyond $t = 80$, the time of concentration of the water-shed may be taken as a maximum without serious error. Having determined the time for the maximum run-off, the values of $C$ and $i$ are taken from

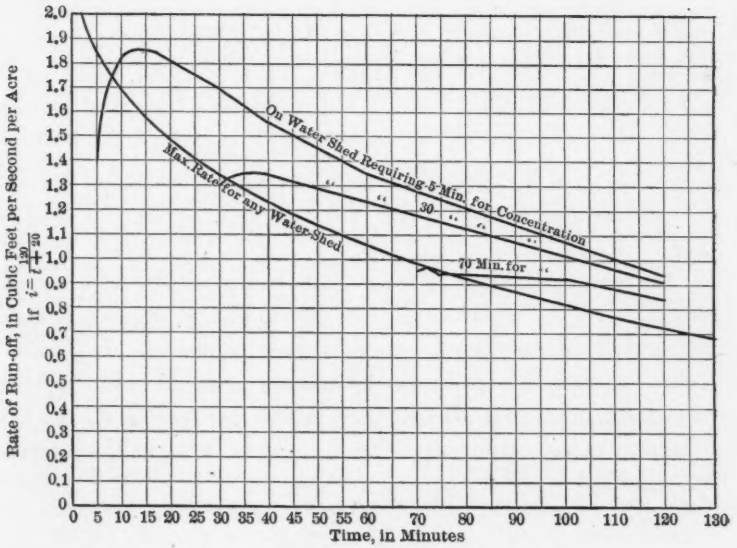



FIG. 11.

their respective curves, or from the curve on Fig. 11, and the result is obtained for the impervious area. The run-off from the pervious areas must be estimated separately, as outlined above.

Any special case, the rain rate being given, would be solved by taking the value of $C$ from the curves in one, or all, of the foregoing ways, and applying it to the rainfall for the rate of run-off.

If an exponential curve that gives smaller values for long-time storms, like Curve 9 on Fig. 1, $i = \frac{32}{t^{\frac{4}{5}}}$, be used to show the relation between the maximum rainfall and run-off, a curve somewhat similar to the McMath form may be deduced from the foregoing laws. This curve shows the relation of the McMath curve to the foregoing deductions better perhaps than can be done by substituting rational values for the time and the rainfall in the original formula, as was done by the writer in the discussion of the paper* by W. C. Parmley, M. Am. Soc. C. E., on the Walworth sewer.

If $Q = A\ C\ i$, for $C$ substitute its value for the time of the water-

* *Transactions*, Am. Soc. C. E., Vol. LV, p. 341.

shed, $C = 0.175\ t^{\frac{1}{3}}$ inasmuch as Curve 9 gives values too great for short periods, this excess will be offset by taking the value of $C$ at the time for concentration, instead of the time of maximum run-off, which occurs a few minutes later if the time for concentration is short. For a rainfall in which $i = \frac{32}{t^{\frac{4}{5}}}$, in which $t = \frac{l}{V}$, $V$ being the average velocity, in feet per minute, and $l$ the greatest length of sewer, in feet, in a rectangular district twice as long as wide, is equal to $369\ \sqrt{A}$.

For an average value of $V$ substitute in the standard formula for flow, $v = c\ \sqrt{r\ s}$, express $s$ in terms of $S$; give $c$ an average value of 80; and, as the relation between $Q$ and the diameter is expressed by the equation of a parabola, the average hydraulic mean radius is two-thirds of the greatest hydraulic radius, and $60\ v = V$. By substitution, these values reduce to $V = 84\ \sqrt[5]{A\ S^2}$, and, by further substitution,

$$Q = 2.8\ A^{0.86}\ S^{0.187},$$

or

$$Q = 2.8\ A\ \frac{S^{0.187}}{A^{0.14}}$$

for totally impervious areas. This gives a curve which approximates the McMath curve in form, but in which the values are somewhat greater, probably due to an irrational method of modification of the McMath formula to apply to perfectly impervious surfaces, the experiments having been made on areas with considerable pervious surface. It agrees more closely with the average values of the New York diagrams and Mr. Parmley's curve, and shows that the foregoing formula can be made to fit roughly the experimental data on which they are based, as well as explain the results of any individual storm. The great difficulty with formulas like the preceding, as has been demonstrated, is to modify the coefficients to fit all conditions rationally. The assumed values and significance of $C$ and $R$ being only the roughest of approximations, the factors affecting their values are quite generally misunderstood, especially in the Hawksley, Bürkli-Ziegler, McMath, and Parmley forms. If $C$ is made to represent only the percentage of impervious area, and is considered constant for all times, then it does not represent the ratio between rainfall and run-off, but is simply a coefficient of area, and whatever variable factors this ratio contains are thrown

into the so-called rainfall coefficient, $R$, which has but little relation to the actual rainfall, and the modification of which modifies other factors than the rainfall.

In order to modify the formula deduced above for different amounts of impervious area, the $A$, in the original form, $Q = A\ C\ i$, must be made equal to the amount of impervious area, but the $A$, the equivalent for $l$, and in the denominator, should be given the full value of the total area. Any other direct modification is misleading, and would apply only roughly in special cases, where the percentage of impervious area is large. All formulas of this kind are solutions of special cases, and, consequently, are limited in their application. The formula,

$$Q = \frac{C\ \frac{105}{l}}{84\ \sqrt[5]{A\ S^2}} + 25$$

suggested by the writer in a previous discussion, is more rational and general, but does not provide for the variable, $C$, and, therefore, is inaccurate for very large and for very small water-sheds.

The only safe method of designing, if anything more than a rough approximation is desired, therefore, is to analyze each case by itself, applying the principles and relations as deduced above, and being guided by the general form, $Q = A\ C\ i$.

The results of each method or formula, for the areas and slopes indicated, are compared in Table 4.

In order to make the comparison of the formulas on the merits of the general form, rather than on the special value of any coefficient, and also to serve as a guide in the selection of proper coefficients, the letter, $C$, in each case, is taken to represent the percentage of equivalent impervious area, and the letter, $R$, to include all other constant factors of rainfall and run-off; but, $C'$ indicates the relation or ratio of the rainfall to the run-off. The value of $R$ is determined as follows: $C$ is given a value of 0.5, $A = 100$, and $S = 10$; the value of $Q$ is obtained by working out Formula 9 for $A = 100$ and $S = 10$, and is 90. These values are substituted in each formula, and the equation is solved for $R$. The values thus obtained are given in Column 3. With this value for $R$, and 0.5 for $C$, the results in Columns 4 to 7 are obtained.

TABLE 4.—Comparison of Results of Run-off Formulas, etc., for the Areas and Slopes Indicated.

| (1) No. | (2) Formula. | (3) Values of $R$. If $C = 0.5$, $Q = 90$, $A = 100$, $S = 10$ | (4) 10 Acres. | | (5) 100 Acres. | | (6) 1 000 Acres. | | (7) 10 000 Acres. | | (8) Maximum value of $CR$ ordinarily used. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $S = 1$, $t = 9.0$ | $S = 10$, $t = 3.5$ | $S = 1$, $t = 17$ | $S = 10$, $t = 7$ | $S = 1$, $t = 35$ | $S = 10$, $t = 14$ | $S = 1$, $t = 69$ | $S = 10$, $t = 27$ | |
| 1 | $Q = A\,C\,R\sqrt[4]{\frac{S}{A}}$ | 3.2 | 9 | 16 | 50 | 90 | 285 | 507 | 1 600 | 2 850 | 1.4 |
| 2 | $Q = A\,C\,R\sqrt[4]{\frac{S}{A}}$ | 3.2 | 9 | 16 | 50 | 90 | 285 | 507 | 1 600 | 2 850 | 2.7 |
| 3 | $Q = A\,C\,R\sqrt[5]{\frac{S}{A}}$ | 2.85 | 9 | 14 | 57 | 90 | 357 | 572 | 2 258 | 3 570 | 2.2 |
| 4 | $Q = A\,C\,R\sqrt[6]{\frac{S^{1.62}}{A}}$ | 2.08 | 7 | 13.7 | 48 | 90 | 330 | 614 | 2 236 | 4 170 | 1.62 |
| 5 | $Q = A\,C\,R\sqrt[6]{\frac{S^{1.5}}{A}}$ | *4.00<br>2.18 | 13.6<br>7.4 | 24<br>13 | 92<br>50 | 165<br>90 | 634<br>342 | 1 120<br>613 | 4 300<br>2 346 | 7 660<br>4 175 | ....<br>4.0 |
| 6 | $Q = A\,C\,R\sqrt[6]{\frac{S^{\frac{1}{2}}}{A\,R}}$ | 4.04 | 11 | 13.2 | 74 | 90 | 505 | 612 | 3 450 | 4 180 | 1.837 |
| 7 | $Q = A\,C\,R\frac{S^{0.187}}{A^{0.13}}$ | *2.8<br>2.23 | 10<br>8.0 | 16.0<br>12.4 | 73<br>59 | 113<br>90 | 533<br>424 | 819<br>650 | 3 856<br>3 071 | 5 931<br>4 723 | ....<br>2.8 |
| 8 | $Q = A\,C'\frac{105}{\frac{l}{84\sqrt[5]{A\,S^2}} + 25}$ | .... | 10.5 | 12.0 | 83 | 111 | 595 | 916 | 3 798 | 6 865 | .... |
| 9 | $Q = A\,C'\,i$, and $i = \frac{120}{t+20}$ | .... | 8.6 | 9.5 | 78 | 90 | 640 | 800 | 5 000 | 6 900 | .... |
| 10 | $Q = A\,C'\,i$, and $i = \frac{32}{t^{\frac{4}{5}}}$ | .... | 10 | 16.0 | 73 | 113 | 533 | 819 | 3 856 | 5 931 | .... |

* Value given by author of formula.

In each case an ideal water-shed of rectangular shape, and twice as long as wide, is assumed.

Table 4 does not show how much difference in the rate of run-off would be made by a change in shape, or in resistance to flow. For example, in Column 5, if the 100 acres with $S = 10$ had been of such shape that its length was $2\frac{1}{2}$ times as great as for the area considered, the run-off given by Formulas 8, 9 and 10 would have been changed to the figures given by the flat slope, $S = 1$, while the results from Formulas 1 to 7 would remain unchanged. Formulas 9 and 10 show the relative value of the two rainfall curves used.

Column 8 gives the maximum values of $C\ R$ in ordinary use, but, except in Formulas 4 and 7, they are not intended to provide for perfectly impervious surfaces.

The writer desires to express his thanks and appreciation for data, aid, and suggestions, kindly furnished by Messrs. E. Kuichling, Rudolph Hering, F. L. Ford and M. L. Hastings.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## TWENTY YEARS' RUN-OFF, AT HOLYOKE, MASS., OF THE CONNECTICUT RIVER.*

By Clemens Herschel, M. Am. Soc. C. E.

While Hydraulic Engineer of the Holyoke Water Power Company, 1879-1889, the writer instituted a system of keeping a daily record of the discharge of the Connecticut River at Holyoke, which was continued, after his departure, by his old-time assistant and successor, A. F. Sickman, Assoc. M. Am. Soc. C. E., until a full 20 years' record had been obtained, 1880 to 1899, inclusive. The record could not be continued because in 1900 the new stone dam of the company† flowed the water back on the old dam, and, by causing irregularity of flow over both dams, made further weir gaugings at these dams impossible. It seems desirable that the record of these 20 years' gaugings should be published in permanent form, so as to become, and remain, available to engineers, and the Holyoke Water Power Company having kindly furnished them, they are herewith given.

The figures in Table 1 are in cubic feet per second. They give the average for that 24 hours, and include water drawn through tur-

* This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

† *Transactions*, Am. Soc. C. E., Vol. XV, p. 543.

bine wheels; wasted over the dam; estimated leak of the dam; leak of the canals; and water used for purposes other than power.

It would serve no useful purpose to enter into a disquisition as to how the figures were arrived at. The hydraulic work at Holyoke has been carefully done, and the results may be considered more accurate than river gaugings as ordinarily found by the use of current meters and the like.

The drainage area, as determined from the best maps available in 1880, is 8 144 sq. miles.

Nor will the subject of rainfall be more than mentioned in passing. The object of this paper is the practical one of serving engineers in forming a judgment of what the discharge of the Connecticut River, or of a similar stream, similarly situated, may be expected to be during a series of years. For this purpose, a knowledge of rainfall is of no importance. What we wish to arrive at is river-flow, and this is reached better by gauging the river than by measuring rainfall, and then theorizing about and computing the river-flow from a computed average rainfall on the drainage area.

It is also well known that, with the same computed rainfall, the discharge of a river will vary greatly in different years; that a larger rainfall often produces a smaller run-off, depending on the distribution of the rainfall during the year and other such causes; and, generally, it is high time that rainfalls cease to have the attention given them as in the illogical reports on stream-flow of the past; and that considerations of stream-flow of rivers direct, no matter whence or how generated or originating, take their place.

The years when the gaugings here given were made need also not be given great weight in the discussion of these gaugings. Twenty years is a long enough period to present the presumable average or type of a like period in the future. As will presently appear, this consideration had influence in determining the manner of representing the 20 years' records in Table 1.

In the original, these 20 years' records were plotted in the form of twenty curves, one for each year, and formed, by plotting in the order of their magnitude and irrespective of the dates when they obtained, the gauged discharges of the river on the 312-314 week days of each of the 20 years in question. On Sundays, no gaugings were made, and, in the original plot, the Sundays present blank spaces.

TABLE 1.—TWENTY YEARS' FLOW OF THE CONNECTICUT RIVER.

Figures Represent Cubic Feet per Second in 24 Hours.

| 1880. | 1881. | 1882. | 1883. | 1884. | 1885. | 1886. | 1887. | 1888. | 1889. | 1890. | 1891. | 1892. | 1893. | 1894. | 1895. | 1896. | 1897. | 1898. | 1899. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 44 100 | 49 050 | 43 650 | 68 300 | 71 900 | 63 950 | 80 150 | 85 500 | 99 750 | 37 800 | 46 750 | 67 300 | 63 100 | 94 350 | 43 300 | 115 000 | 112 050 | 75 350 | 76 150 | 82 500 |
| 28 900 | 45 100 | 30 850 | 36 550 | 49 500 | 44 350 | 42 700 | 63 550 | 65 150 | 32 300 | 39 650 | 54 450 | 42 950 | 42 550 | 33 400 | 50 800 | 61 950 | 53 650 | 50 750 | 67 250 |
| 22 900 | 32 850 | 25 900 | 25 200 | 37 950 | 36 650 | 36 600 | 50 150 | 49 850 | 29 050 | 36 550 | 43 000 | 31 700 | 36 950 | 26 550 | 33 550 | 37 300 | 44 200 | 41 550 | 45 900 |
| 19 800 | 25 200 | 23 500 | 19 950 | 30 750 | 30 700 | 29 250 | 37 000 | 40 600 | 26 450 | 33 500 | 32 750 | 27 200 | 32 000 | 18 550 | 24 700 | 26 150 | 37 000 | 31 500 | 23 200 |
| 17 550 | 20 100 | 22 150 | 16 550 | 27 700 | 25 950 | 25 450 | 27 600 | 34 600 | 24 800 | 30 050 | 28 800 | 23 500 | 28 200 | 16 050 | 21 950 | 23 150 | 32 950 | 25 850 | 17 700 |
| 15 250 | 17 800 | 20 800 | 15 200 | 26 200 | 22 550 | 19 750 | 22 900 | 31 700 | 23 200 | 28 200 | 24 350 | 20 800 | 23 450 | 15 100 | 18 850 | 20 100 | 28 300 | 22 800 | 15 400 |
| 14 250 | 16 600 | 18 900 | 13 000 | 24 250 | 19 200 | 17 600 | 20 550 | 30 000 | 21 350 | 26 250 | 22 250 | 18 050 | 17 700 | 13 950 | 16 200 | 18 300 | 26 350 | 21 000 | 14 000 |
| 11 750 | 15 100 | 16 850 | 10 450 | 22 000 | 16 950 | 14 700 | 18 650 | 26 350 | 20 500 | 24 600 | 20 250 | 17 150 | 15 100 | 13 000 | 13 550 | 17 150 | 24 500 | 19 200 | 12 300 |
| 10 900 | 14 300 | 15 300 | 9 000 | 18 950 | 16 200 | 14 050 | 17 000 | 24 150 | 19 400 | 23 150 | 19 050 | 15 600 | 12 700 | 11 750 | 10 900 | 15 050 | 22 950 | 17 850 | 11 400 |
| 10 050 | 12 900 | 14 500 | 8 250 | 15 550 | 14 150 | 12 560 | 15 250 | 21 850 | 18 500 | 21 700 | 17 850 | 14 550 | 11 250 | 10 000 | 9 600 | 13 900 | 20 350 | 16 250 | 10 450 |
| 8 900 | 11 750 | 13 500 | 7 600 | 13 150 | 13 250 | 12 100 | 14 200 | 20 200 | 17 450 | 19 650 | 16 600 | 13 800 | 9 950 | 8 800 | 9 050 | 12 800 | 19 200 | 15 150 | 9 950 |
| 8 500 | 11 000 | 12 500 | 7 000 | 12 300 | 12 400 | 11 500 | 12 950 | 19 250 | 16 650 | 18 450 | 14 500 | 13 250 | 9 100 | 8 200 | 8 400 | 11 650 | 18 050 | 14 400 | 9 000 |
| 8 300 | 10 050 | 11 600 | 6 550 | 11 100 | 11 550 | 10 900 | 12 300 | 18 250 | 16 100 | 17 750 | 13 700 | 12 600 | 8 500 | 7 800 | 7 750 | 10 700 | 16 800 | 13 750 | 8 150 |
| 7 950 | 9 400 | 10 500 | 5 950 | 10 300 | 11 050 | 10 250 | 11 450 | 17 600 | 15 550 | 17 100 | 12 500 | 12 200 | 7 800 | 7 400 | 7 250 | 9 800 | 16 100 | 12 950 | 7 750 |
| 7 500 | 8 850 | 9 250 | 5 150 | 9 250 | 10 550 | 9 800 | 10 750 | 16 700 | 14 650 | 16 050 | 11 350 | 11 600 | 7 300 | 6 950 | 6 300 | 9 300 | 15 300 | 12 450 | 7 200 |
| 7 300 | 7 900 | 8 350 | 4 850 | 8 750 | 9 200 | 9 600 | 10 150 | 15 600 | 14 250 | 14 950 | 10 500 | 11 100 | 6 850 | 6 550 | 6 050 | 8 550 | 13 950 | 12 000 | 6 600 |
| 6 900 | 7 150 | 7 500 | 4 650 | 8 150 | 8 850 | 9 200 | 9 850 | 14 300 | 13 550 | 14 400 | 9 600 | 10 250 | 6 450 | 6 250 | 5 800 | 8 050 | 13 200 | 11 550 | 6 050 |
| 6 350 | 6 650 | 6 950 | 4 400 | 7 550 | 8 300 | 8 850 | 9 500 | 13 500 | 12 800 | 13 700 | 8 800 | 9 500 | 6 050 | 5 950 | 5 200 | 7 700 | 12 650 | 10 700 | 5 650 |
| 5 350 | 6 350 | 6 400 | 4 100 | 7 200 | 8 050 | 8 500 | 9 150 | 12 400 | 12 150 | 13 400 | 7 600 | 9 100 | 5 900 | 5 700 | 4 900 | 7 150 | 11 800 | 10 150 | 5 400 |
| 4 600 | 5 500 | 5 750 | 3 900 | 6 700 | 7 800 | 8 100 | 8 850 | 11 400 | 11 650 | 12 800 | 7 200 | 8 600 | 5 650 | 5 450 | 4 750 | 6 850 | 10 550 | 9 700 | 5 350 |
| 4 000 | 5 200 | 5 050 | 3 750 | 5 950 | 7 650 | 7 800 | 8 500 | 10 600 | 11 250 | 12 050 | 6 650 | 8 150 | 5 200 | 5 200 | 4 550 | 6 500 | 10 200 | 9 200 | 5 250 |
| 3 650 | 4 750 | 4 850 | 3 650 | 5 700 | 7 250 | 7 400 | 8 250 | 9 200 | 10 850 | 11 400 | 6 100 | 7 850 | 4 900 | 5 050 | 4 350 | 6 250 | 9 700 | 8 750 | 5 150 |
| 3 500 | 4 200 | 4 400 | 3 600 | 5 600 | 6 800 | 7 050 | 7 900 | 8 [illegible]00 | 10 00 | 10 500 | 6 000 | 7 500 | 4 750 | 4 950 | 4 100 | 6 050 | 9 150 | 8 450 | 5 000 |
| 3 350 | 3 800 | 4 150 | 3 500 | 5 350 | 6 600 | 6 600 | 7 650 | 8 000 | 9 850 | 9 900 | 5 550 | 7 000 | 4 600 | 4 800 | 3 950 | 5 800 | 8 550 | 8 050 | 4 650 |
| 3 200 | 3 700 | 3 800 | 3 450 | 5 100 | 6 250 | 6 000 | 7 550 | 7 650 | 9 500 | 9 600 | 5 250 | 6 600 | 4 450 | 4 750 | 3 800 | 5 250 | 8 000 | 7 700 | 4 500 |
| 3 000 | 3 600 | 3 700 | 3 400 | 4 900 | 5 900 | 4 900 | 7 350 | 7 300 | 9 150 | 9 000 | 5 100 | 6 400 | 4 350 | 4 650 | 3 600 | 4 900 | 6 500 | 7 550 | 4 150 |
| 2 850 | 3 400 | 3 650 | 3 350 | 4 600 | 5 550 | 3 900 | 7 150 | 7 100 | 8 650 | 7 950 | 4 850 | 6 150 | 4 250 | 4 500 | 3 500 | 4 650 | 5 250 | 7 200 | 3 950 |
| 2 350 | 3 100 | 3 550 | 3 250 | 4 350 | 5 450 | 3 450 | 6 600 | 7 000 | 8 000 | 7 250 | 4 600 | 5 900 | 4 050 | 4 250 | 3 400 | 4 500 | 5 000 | 6 700 | 3 550 |
| 2 350 | 3 000 | 3 500 | 3 100 | 4 150 | 5 250 | 3 300 | 6 300 | 6 800 | 7 550 | 6 850 | 4 400 | 5 550 | 3 900 | 4 000 | 3 300 | 4 400 | 4 900 | 6 150 | 3 300 |
| 2 150 | 2 950 | 3 450 | 2 950 | 4 000 | 5 000 | 3 200 | 6 150 | 6 500 | 7 250 | 6 300 | 4 150 | 5 150 | 3 850 | 3 600 | 3 150 | 4 300 | 4 700 | 5 850 | 3 200 |
| 2 150 | 2 950 | 3 250 | 2 900 | 3 700 | 4 850 | 3 150 | 5 750 | 6 300 | 7 000 | 5 950 | 4 050 | 4 950 | 3 750 | 3 350 | 3 150 | 4 150 | 4 450 | 5 050 | 3 050 |
| 2 050 | 2 950 | 3 150 | 2 850 | 3 600 | 4 600 | 3 000 | 5 400 | 5 800 | 6 600 | 5 300 | 3 600 | 4 700 | 3 600 | 3 000 | 3 050 | 3 900 | 4 350 | 4 750 | 2 800 |
| 2 050 | 2 950 | 3 000 | 2 750 | 3 500 | 4 300 | 2 800 | 4 600 | 5 350 | 6 250 | 4 800 | 3 500 | 4 500 | 3 350 | 2 750 | 3 000 | 3 750 | 3 900 | 4 400 | 2 700 |
| 2 000 | 2 950 | 2 900 | 2 500 | 3 100 | 4 150 | 2 700 | 4 300 | 4 800 | 5 900 | 4 300 | 3 150 | 4 400 | 3 200 | 2 450 | 2 950 | 3 450 | 3 700 | 4 000 | 2 500 |
| 1 950 | 2 950 | 2 850 | 2 300 | 2 950 | 3 850 | 2 500 | 4 150 | 3 700 | 4 650 | 3 700 | 2 950 | 4 300 | 3 050 | 2 350 | 2 900 | 2 850 | 3 550 | 3 600 | 2 400 |
| 1 750 | 2 850 | 2 500 | 2 150 | 2 700 | 3 550 | 2 350 | 3 750 | 3 450 | 3 650 | 3 550 | 2 900 | 4 150 | 2 800 | 1 900 | 2 850 | 2 700 | 3 350 | 3 450 | 2 350 |
| 1 650 | 2 700 | 2 400 | 1 950 | 2 650 | 3 050 | 2 100 | 3 650 | 3 000 | 3 100 | 2 750 | 2 750 | 3 000 | 2 550 | 1 600 | 2 700 | 2 100 | 3 000 | 3 200 | 2 250 |

To have reproduced these twenty curves would, it was thought, not be so convenient in use as to present their data in the form of a table. And to attempt to plot all twenty of the curves to the same co-ordinates would require color printing to prevent confusion.

Abstaining now from presenting a record of the precise years when the gaugings were made, and aiming only at presenting a 20 years' table for future use, it seems allowable to make Table 1 by giving, in the head line, the maximum day of flow of each of the 20 years, and thereafter of every tenth day following, arranged in order of size, with the lowest day's run in the year as a last entry in each column. When such tenth day happened to be Sunday, the average of the Saturday and Monday, preceding and following, was given as the flow for that tenth day.

On the other hand, should it ever be required to reproduce the record of any one certain year from Table 1, it will only be necessary to replot that year from the indications just given.

For water-power purposes, the most instructive part of Table 1 will be the lower half of it—below a selected row of the figures between the two heavy horizontal lines.

It will be found that this selected horizontal row represents the stream-flow which, by a process of "survival of the fittest," has been found on streams in general to be the measure of quantity for which it is the part of a prudent mill-owner or water-power company to supply wheel capacity, when setting the wheels to be driven on that river, at that point. A greater wheel capacity is not profitable because the wheels stand idle too long. A less wheel capacity causes too much water to run by unused.

To furnish the necessary power for making all the stream-flows below the selected horizontal line of figures supply a uniform amount of power, is the office of the auxiliary steam plant, which is always requisite (on the outflow of the Great Lakes alone excepted) to cause the investment in dams, canals, power-houses, etc., to yield its greatest possible return.

Even so, and in spite of the ordering of 20 years' data, represented by Table 1, we find the upper of these horizontal lines to vary from 15 600 to 4 850; and the lower one, from 12 050 to 3 750.

The lowest run for the whole year varied from 3 650 to 1 600; showing that double, three-fold, and even more times, the lowest

run of the river is allowable, as representing the proper turbine-wheel capacity to be set, on rivers of this class.

Other computations may be made and lessons drawn from Table 1; such as the greatest auxiliary steam power that will be needed on any one day to bring the power furnished by the river up to the desired average or "peak-load" power; the average auxiliary steam power needed during an average year to bring the output of water-power during such a year up to the desired average, or "peak-load," annual output of power; and many more such questions as they arise.

It is much to be desired that the United States Geological Survey will publish its records of stream-flow in some such form as that here exemplified.

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# PAPERS AND DISCUSSIONS.

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## RECENT PRACTICE IN HYDRAULIC-FILL DAM CONSTRUCTION.

### Discussion.*

By Clemens Herschel, M. Am. Soc. C. E.

Clemens Herschel, M. Am. Soc. C. E. (by letter).—To the principles laid down at the beginning of this paper, the writer would add one more; namely: an earth dam should have, to be safe for an indefinite period of time, somewhere in its cross-section, a durable element, or member of construction, capable of resisting the attacks of burrowing animals not infrequently experienced from the up-stream, as well as the down-stream, side, and from beneath the surface, for the time being, of the water; one, at the same time, capable of arresting the further progress of any veins of water that may penetrate the interior of the dam, whether caused by settlement, sand strata, as mentioned by the author, drying-out cracks, burrowing animals, or any other cause. Mr. Herschel.

There appears to be no logical reason why an earth dam, built by the hydraulic-fill method for excavating, conveying and solidifying the earth of which it is composed, in preference to steam, or any other kind of shovel work, carting or railroading, and spreading, sprinkling and rolling, should be built according to materially different principles for insuring safety and permanency in one case than in the other.

The author of the paper places the reason for using the hydraulic-fill method in a saving of cost by that method for the opera-

* This discussion (of the paper by James D. Schuyler, M. Am. Soc. C. E., printed in *Proceedings* for October, 1906), is printed in advance of the presentation of the paper, which will occur December 19th, 1906. Further communications on the subject will be presented to the Society at that meeting and subsequently printed with the paper.

Mr. Herschel. tions just described, and no other; a reason very well founded in a multitude of cases, and making the examples and data given of the highest interest to all concerned with the construction of reservoir dams.

Still, the method has its defects and limitations. It needs, that it may be adopted, a body of earth situated at a higher elevation than the body of the dam to be built, and not too far away. Possibly some day we shall be able to pump a heavy mixture of earth and water up-hill; at present the most that can be done is to pump up the water, and let it and the earth mixed with it run down again.

It necessitates flatter slopes, that is, a greater volume in the earth dam, than dams built by the ordinary method, thus off-setting, to some extent, the saving effected in price per cubic yard of material deposited in the dam by the hydraulic method.

It seems to require, for one reason or another, a longer time than would otherwise be necessary.

No one is probably more disposed than the writer, to admire the resourcefulness and skill of the Pacific Coast hydraulic engineers in general, exhibited these 40 years in their works, and of the author in particular, but the nature of the demands made upon them has insisted that they meet those demands in nearly, though not in all, cases with works built with a minimum expenditure of labor and of cost, even if at the expense of a certain degree of permanency.

Thus, the entrancing looking wooden flumes of the cañons have already rotted out to such an extent that the proprietors and the water-buying public, no less than the engineers, have been made ready to consider more permanent structures. Signs are not wanting that wooden stave pipes are going the same way that the wooden flumes did. And similarly, all forms of dam construction will have to be designed and built with every regard given to permanency, as in the older settled portions of the country; the more or less temporary forms of structure having served their high and useful purpose of enabling the country to be settled.

These remarks, of course, do not refer to the earth and stone of the dams shown, as there can be nothing more durable than earth and stone, but are made in behalf of a durable core-wall of some sort, always to be placed in any and every earth dam, but which appears to be missing in all the designs illustrated. There is an instance of a plank fence in one case, but that cannot be considered as a durable core-wall, either against the tooth of time, or, when placed up to the flow line, against the tooth of the animal creatures that inhabit such reservoirs.

In the case of water-power canals, some 10 ft. deep, canal banks built with a plank core-wall have remained water-tight after the

planks had been converted into a streak of loam; but with the danger ever present, and occasionally occurring, that by reason of some burrowing animal, the canal bank would begin to leak, or even give way. Mr. Herschel.

In the discussion on "Reservoirs with High Earthen Dams in Western India,"* the writer has given the results of his experience in the construction of earth dams, and his ideas of the essentials of such structures. These are, that an earth dam is a structure composed of an unstable water-tight curtain fastened in a water-tight manner across the water-tight surface of a valley; extending up to a horizontal line, and made stable or supported on each side by an earth fill, properly placed and protected against wave and rain wash on the outside and top. There would be no need of a core-wall, if every man at work in the construction of the dam had the intelligence, will and ability to put into it nothing but perfect work. But such embankments are the outcome of the work of hundreds, or of thousands, of the very lowest class of labor, and, strive as the directing mind may, imperfections will creep in, and remain in the completed work. If water once commenced to penetrate into an earth dam, or to percolate, the channels of percolation could readily enlarge, unless there was somewhere a reliable water stop; and to furnish this is the office of the core-wall. Even if the core-wall should crack, it would still fulfill an important part of its duty; for at that point the channel of percolation could not enlarge, thus limiting the amount of water that could percolate, and in all probability causing the leak to close itself instead of enlarging.

None of the arguments ever brought against the use of a core-wall in earth dams have had any weight when tested by experience, or an analysis; and nothing weightier than argument unsupported by experience ever has been brought against them.

The Canistear Dam, in New Jersey, described in the papers before cited, was built between June 10th and November 1st, 1896, less than 5 months, and has been in use ever since, with only nominal repairs. All the work on this reservoir, several dams included, cost about $341 000, and would have cost about $295 000, if not built by night and day work; if built only by day work, as it has been practiced on works built under the supervision of the writer, it would have required more than double the time stated. Considering the bill of quantities which follows, the writer would claim for this work the record time anywhere, and at least a fair record for low cost for that quality of work on the Atlantic Coast. This may also serve to prove that the core-wall, and the spreading, sprinkling and rolling method of building earth dams does not necessarily entail years of time in which to construct them. On

* *Minutes of Proceedings*, Inst. C. E., Vol. CXXXII, p. 252, 1897-98; *Engineering News*, Sept. 7th, 1905.

Mr. Herschel. the contrary, it may in settled localities excel, in this frequently very important particular, the hydraulic-fill method.

The bill of quantities of the Canistear Dam was as follows:

| | | |
|---|---|---|
| Main dam and reservoir, clearing | 440 | acres |
| Main dam and reservoir, grubbing | 440 | " |
| Excavation on dam site | 11 000 | cu. yd. |
| Gate-house cut, rock | 1 200 | " " |
| Gate-house cut, earth | 5 700 | " " |
| Core-wall excavation, rock | 2 450 | " " |
| Core-wall excavation, earth | 2 100 | " " |
| Core-wall, concrete | 8 000 | " " |
| Dam, earth, including paving | 98 000 | " " |
| Gate-house masonry, brick | 100 | " " |
| Gate-house masonry, stone | 1 500 | " " |
| Gate-house masonry, concrete | 150 | " " |
| Gate-house fittings, pipes, valves, stairway, etc. | | |
| New road | 11 562 | ft. |

OVERFLOW DAM.

| | | |
|---|---|---|
| Excavation, earth | 2 700 | cu. yd. |
| Excavation, rock | 1 450 | " " |
| Masonry | 4 500 | " " |

AUXILIARY DAM, No. 1.

| | | |
|---|---|---|
| Clearing site of dam | 850 | cu. yd. |
| Excavation for core-wall, rock | 80 | " " |
| Excavation for core-wall, earth | 150 | " " |
| Core-wall, concrete | 300 | " " |
| Earth dam, including paving | 1 400 | " " |

AUXILIARY DAM, No. 2.

| | | |
|---|---|---|
| Clearing site of dam | 950 | cu. yd. |
| Excavation for core-wall, rock | 20 | " " |
| Excavation for core-wall, earth | 600 | " " |
| Core-wall, concrete | 750 | " " |
| Earth dam, including paving | 2 450 | " " |

Closely allied with the question of time is that of the necessary volume of the dam. That excess of volume may merely embarrass construction, and, at the same time, in no wise contribute to the safety of an earth dam, is proven, amongst other ways, by the cross-section proposed for the Gatun Dam shown on Plate XIV of the

Report of the Board of Consulting Engineers for the Panama Canal. Mr. Herschel.

This is the type of dam presented only by the lock-canal minority of that tribunal, the Board having held that one form of reservoir-dam construction was appurtenant to a lock canal and another form was appurtenant to a sea-level canal; precisely the same members of the Board having voted for each form of dam construction according as they voted for a lock canal, or a sea-level canal.

But the history of the origin of this monster dam design (the dam has a base of over half a mile, to retain 85 ft. of water) is necessary, before it can be at all understood how it could have arisen; and, at the same time, before the fallacious reasoning by which it is now justified can be related. Mr. Schuyler has suggested the hydraulic-fill method for building this dam and others at Panama, but no advantage can be taken of the suggestion, so long as the above-described cross-section prevails, and the putting into it of waste earth from the canal excavation, is insisted on.

The origin of the cross-section referred to is to be found in Massachusetts, and begins with the idea, that removing the top soil a foot or more in depth from over the several square miles of a reservoir site will materially improve the quality of the water to be stored and drawn, as compared with the same water if stored in such a reservoir built as they have been hitherto built in hundreds of examples. This has been called an idea because no proof has ever been offered that such results would follow, or have followed; nor can such proof be furnished except solely by practice. Argument may indeed be made on the other side, but this feature of the case is beside the present question.

In one instance, at least, this so-called stripping work has been done, and has resulted naturally in the accumulation of a very large amount of waste earth—several million cubic yards of it. This all had to be put somewhere, and, as an earth dam formed part of the works, the choice was presented of making a monumental mound of it, or of disposing of it on the down-stream side of the earth dam, and as a part of it; sloping it off to a similarly enormous distance to that already described, and with a slope so flat as to resemble a lawn or golf ground more than the outside of a reservoir dam.

Thus far no harm has been done to designs for reservoir dams in other places, but when this dam of superfluous dimensions is cited as an example of design to follow; whether there be an excess of excavation to dispose of or not; whether, having an excess of excavation to dispose of, it can be disposed of in a less expensive place and manner, or not; it is proper to protest against the general construction of earth dams of these startling and excessively costly, yet useless, dimensions.

Mr. Herschel.

To support the same, a new theory of the action of water under pressure, when flowing through the earth, has been brought out, which constitutes the fallacy to which reference has been made. This is, that such water under pressure—in this case starting from the up-stream reservoir—when moving through or let loose in the earth, is bound to proceed in a direction parallel to the surface of the down-stream slope of the dam which has been described, or in a nearly horizontal direction, and thus be compelled to move very slowly; when in fact, and as any observer of a spouting spring, or of the escaping water of a break in a pipe has seen, water under pressure will always seek the surface by lines of least resistance. If it need turn a square corner and escape vertically, instead of continuing to flow horizontally, and thus make wholly useless the half mile of tail or fringe to the dam which has been described, it will not hesitate to do so; leaving the many millions of cubic yards of this fringe, distributed in layers, sprinkled and rolled at great expense, or else put in by hydraulic-fill, wholly wasted below it; or even proceeding to flow over and cut into the surface of such a half-mile fill.

This notion of water flowing only in horizontal straight lines is a hard one for the modern engineer to get rid of. In his youth he was taught all about the "threads" and the "filaments" in which water moves, and it will not be until these conceptions of the school books are rooted out of the books and out of past scholars, that engineers will become, on these lines, less gullible. To this day the outlet gates of reservoirs for a domestic supply of water are placed at several elevations for the alleged purpose of enabling different "layers" of the contained water to be drawn. Whereas everyone knows, or by reflection may know, that water is as likely to reach such an outlet from above, or from below, or from any direction bounded by a hemisphere within the reservoir, as from a point in the same horizontal plane as the outlet opening.

It is this same class of false reasoning which would make us believe that water from up stream, or from within a dam, is compelled by inherent predilection to follow lines of resistance that stretch out for half a mile down stream parallel to the surface of a slope piece of that width that has been added to the already sufficient ordinary down-stream slope of an earth dam, rather than turn a square corner and spout out vertically; and that will argue for the construction of such a dam.

For there is also no other valid argument in favor of it. It is a piece of landscape gardening, nothing more. It has been claimed for it, that its great weight will compress the soil for great depths, thus making secure an otherwise insecure foundation. The writer does not think so. It is weight per square foot that counts, not

gross weight, and the greatest weight per square foot is under the center of the dam. Even there, the weight of the dam can affect the consistency of the sub-soil for only a very small depth; and certain it is, if such action is not effective and sufficient under the body of the dam, that adding a fringe a half a mile wide down stream from the body of the dam, will not mend the situation. Mr. Herschel.

Before the author can get a hearing for the hydraulic-fill method which he has suggested for the building of the Gatun and other of the Panama reservoir earth dams, it will be necessary to resolve to dispose of the waste excavation from the canal anywhere and in any manner in which it can be disposed of most economically, rather than save it, in order that it may be placed in an earth dam with a half-mile base by means of a 30-mile haul, to hold 85 ft. of water; about six times the base, and twenty times the volume, for the same depth of water, of the already unusually large and voluminous Necaxa Dam described by the author. This done, a cross-section of these dams more nearly normal may be adopted, and estimates and a plan of campaign made, how most expediently to construct them.

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## ADDITIONAL INFORMATION ON THE DURABILITY OF WOODEN STAVE PIPE.

### Discussion.*

BY MESSRS. SHIRLEY BAKER, CLEMENS HERSCHEL AND D. C. HENNY.

Mr. Baker.

SHIRLEY BAKER, ASSOC. M. AM. SOC. C. E.—The speaker believes that the conclusions drawn in this paper are entirely too general, and in several instances are not supported by the facts as set forth. The practical indestructibility of wood thoroughly saturated with water has become an axiom, so that when the wood of a structure which is designed to act under the condition of saturation decays, it would lead to the supposition that complete saturation was not always maintained, rather than that the fundamental principle, so well proved by time, was at fault.

In his Conclusion 2 the author states, "The magnitude of the water pressure, beyond a moderate head, has had little or no influence in preserving the timber," and yet, from his profile, Fig. 1, the points of renewal, as shown by arrows, are found to be entirely on the lighter pressures.

In Conclusions 4, 5 and 6, the author states in effect, that, where buried, the durability depends on the depth of the backfill and the character of the soil, but in Conclusion 8 he states, "Sound staves have been frequently found contiguous to badly decayed staves," and, in Conclusion 10, "The bruising of the staves during the process of erection seems to have been one of the chief agencies in hastening decay."

* This discussion (of the paper by Arthur L. Adams, M. Am. Soc. C. E., printed in *Proceedings* for September, 1906) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Baker.

These conclusions appear to the speaker to be somewhat contradictory. The fact that sound and decayed staves were contiguous would seem to indicate reasons for decay other than the depth of the backfill and the character of the soil.

The author states that the renewal and repair work in 1905 involved an expenditure of more than one-third of the original cost of the pipe. The speaker believes that this statement should have explanation, otherwise the cost of the repair work, compared with the length of the line, becomes greatly magnified. The Astoria pipe line was built at a time of great financial depression, consequently the cost of construction materials was very low. All engineers and contractors know of the great advance in prices during the last ten years. This advance aided in increasing the cost of this repair work; but, further, the speaker is advised that California redwood was used to a great extent in these repairs, and that redwood is much more expensive than the fir which was originally used.

Table 1 is interesting in a general way, but, since the object of the paper is to place the conditions and amount of repair work fairly before the Society, it would seem that the author has not gone far enough in computing the percentage of repair work to the length of the line. From an economic standpoint, this becomes a matter of cost, and, therefore, should include only the material actually used. The quantity of new material used is clearly shown in the last line of the table, under the caption, "New staves required, equivalent to feet of pipe," where the actual quantity of timber in new staves is reduced to the equivalent length of pipe. The summation of these lengths, or 3 267 ft., compared with the summation of the total length of line, or 39 750 ft., shows that the actual quantity of new pipe built is only about 8% of the line. From the fact that in Table 3 is included the cost of repairing "the damage resulting from two quite extensive land slides," one is led to ask if the replacement required on account of these slides is included in Table 1, and, if so, what length of line was carried away by the slides.

Mr. Bergsvik's opinion that part of the line will need replacing in about 4 years, but that about 2½ miles will last perhaps 10 years more, places the ultimate life of the sections in question at 15 years and 21 years, respectively. Although this is a shorter life than is usually ascribed to wooden pipe, the fact that its use effected a total saving of nearly 50% over the cost of a No. 12 gauge steel pipe of equal capacity,* goes a great way toward justifying its installation.

The durability of wooden stave pipe is, indeed, an important question, as many miles are now in use, and engineers, both in the East and in the West, are continually specifying it in connection with municipal water supply, power plants, outfall sewers and irri-

* Adams, on Astoria Water-Works. *Transactions*, Am. Soc. C. E., Vol. XXXVI, p. 1.

Mr. Baker. gation. The speaker is in possession of several interesting reports on the present condition of wooden pipe lines, and begs to quote from a letter, written under date of January 16th, 1906, by Eugene Carroll, M. Am. Soc. C. E., Superintendent of the Butte Water Company, Butte, Montana, where a length of about 30 miles of 24-in. and 26-in. continuous stave pipe is in operation. Mr. Carroll's letter is, in part, as follows:

"The banded redwood pipe laid at this place in 1892, 1899, and 1900 has a permanent covering of 2 ft. above the top of the pipe. The pipe has been uncovered in places at various times for repairs. The bands look first-rate thus far; they are considerably rusted on the older pipe around the threads, and the nuts are so thoroughly rusted to the band that when we have to remove a band it is necessary to replace it with a new one. These old bands which are removed we use again by welding on a new threading. As far as we know, none of the bands have failed on account of rust. Where bands have been removed or replaced, for various reasons in repairing the pipe, we have had no trouble in replacing them, and do so without shutting off the flow, though I would consider it a good practice in case it was necessary to reband any considerable length of pipe, that the flow be shut off and the pressure removed in order to get an even bearing in recinching the bands.

"In the first pipe we built, in 1892, for a short distance through a rocky cut, we were not particular about backfilling, and considerable of the covering was broken stone. In a short time after using it, we discovered that the staves were beginning to show indications of decay along this portion of the line; believing it was caused from the rock filling, allowing the air to get to the outside of the pipe, thereby causing decay, I had the filling entirely removed and replaced with good dirt on top of the pipe. Since then we have had no trouble, and have never found a stave rotted sufficiently to require its removal. Where the pipe is properly filled with good dirt all around the pipe, the seepage from the pipe keeps the earth damp and practically water-logs the wood, so that I see no reason why we should ever have trouble with rot. The expense of maintaining this pipe has been practically nothing.

"The pipe connects our reservoirs, one 13 miles and the other 22 miles out, with our reservoirs in town. The watchmen, which we have to keep at each reservoir, make a trip over the pipe line once a week. Occasionally, in making these trips, it is necessary to dig out the pipe for small leaks, such as wormholes or butt joints, but, with two exceptions, we have never had to use more than two men in repairing leaks, and have never had to shut off the water. Our two exceptions are: first, during the winter of 1893, ice formed inside of our pipe line, being caused from the fact that our reservoir was not completed, and a jam was caused inside the pipe, bursting it, requiring the shutting off of the water, and about 12 hours to repair it. Last spring, on our new pipe line, a leak developed near one of our valve chambers, and, before it was discovered and the water shut off, a bad wash-out took place, which washed the support away from the pipe line for about 1 000 ft., necessitating the re-

building of the line, taking about four days to do it. This section of pipe last referred to was built by an incompetent foreman at the time, and should have been rebuilt during the original construction, but, on account of the good nature of the writer, was allowed to stand. Mr. Baker.

"Referring to the pipe line built in '92, will say that it is apparently in as good shape to-day as the day it was built, and it is impossible to estimate as to what its future life will be. I can only say that I am so pleased with my experience with wooden pipe for supply lines that I would use it wherever possible in future construction work. It seems to me that, from the fact that the pipe is thoroughly water-soaked, the life of the wooden part should be very great. The nuts seem to be thoroughly rusted on the threads, and, when they are not disturbed, it looks as if the pipe will not need rebanding for many years to come."

CLEMENS HERSCHEL, M. AM. SOC. C. E.—It was about twenty years ago that engineers in the East first heard of stave pipe. The speaker was then living in Holyoke, Mass., and, speaking for the class of engineers who had something to do with water-power in New England, he would say that to them it seemed like a very old institution. It rather amused them to think of people out West having made what they were pleased to term a great invention—this, of wooden stave pipe—when it had been used, in the shape of wooden penstocks, in New England water-powers, very nearly ever since the country was settled. New England engineers thought that it was a great advance to be rid of wooden stave pipe and, instead, to use riveted—in those days—wrought-iron pipe, and, subsequently, steel pipe. Mr. Herschel.

There is just one difference that the speaker can see between wooden stave pipe and wooden penstocks. In the case of water-power and wooden penstocks, it is customary to draw the pipe—empty it—on holidays and Sundays, or at least frequently during the year, whereas, the wooden stave pipe would remain full of water all the time; and he had thought that, perhaps, that might save the wooden stave pipe, where it had not saved the wooden penstocks.

The speaker has told the story a great many times about wooden penstocks, illustrating how they were viewed in New England, and he might as well tell it again. There was one of these old wooden penstocks to take out, and it was done on a Sunday, and the next day he met the mechanic who had had charge of taking it out, and said, "Joe, did you have any trouble about taking that penstock to pieces and getting it out?" "Oh, no," said Joe, "as soon as we got it cleared off, we shoveled it out—no trouble at all." That illustrates the end, the usual end, of a wooden penstock pipe.

It is stated in this paper that the pipe rots from the outside in, until a very thin portion of the wood alone remains sound. That feature, also, is nothing new. In the paper read before the Society

Mr. Herschel. in 1886,* on the preservation of the Holyoke Dam, by the speaker, it is stated that in repairing that wooden dam it had been found that the 6-in. timbers which constituted the covering of the dam, constantly under 20 ft. of water, were rotten from the up-stream side down stream, until there was no more sound wood left than would form a veneer. It was really curious to see how closely those 6-in. timbers came to being rotten clear through and yet have that little veneer on the water side preserved, sometimes not more than $\frac{1}{8}$ in. thick. That is a parallel case to stave water pipe rotting from the outside in.

Mr. Henny. D. C. HENNY, M. AM. SOC. C. E. (by letter).—The writer has read with interest the account of the experience with the stave pipe portion of the gravity supply pipe line of Astoria, Ore., completed in December, 1895. The information contained therein is of the greater interest to him as he was at that time manager of the contracting company, and, for a portion of the time, in personal charge of construction. He is familiar, therefore, with the character of the material which entered into its construction and with the general conditions affecting its life.

Reliable information, regarding the actual condition of structures which are buried, is, as a rule, very difficult to obtain, and, except under the most favorable conditions, can hardly ever be acquired at first hand. Such information as can be secured should therefore be closely sifted from error and exaggeration, and this process of sifting has constituted one of the greatest difficulties in the writer's search after facts of this kind. Even when standing in the relation of consulting engineer for a company operating steel and wooden pipe lines buried underground with which trouble had been experienced, due respectively to corrosion and decay, he has never been enabled to make personal examination, except by the merest accident. Thus the information gathered by him has been fragmentary and unsatisfactory in character. It has been sufficient, however, to lead him to a realization that exceptional conditions may place a limit on opinions previously entertained regarding the life of wooden stave pipe.

It has been generally held that sound wood in a condition of complete saturation will prove to be immune from decay, and that the shell of a wooden pipe, even if under very moderate water pressure, will be fully saturated. A great mass of evidence, constantly increasing, tends to confirm this conclusion under ordinary conditions. Among the large numbers of pipe lines built by others, as well as by the writer, there are in all six individual cases in regard to which he has had knowledge of decay having resulted during a

* "On the Preservation of the Dam at Holyoke, Mass., in 1885, and on Some Studies for a New Stone Dam for the Same Place," *Transactions*, Am. Soc. C. E., Vol. XV, p. 543.

use of 6 years or more. In three of these cases the decay was confined to the immediate vicinity of summits close to or touching the hydraulic grade line, or to places where it was known that the pipe had been running only partially full for a considerable portion of the time. A fourth case was that of a pipe line left unburied, and exposed to the trying atmosphere of Southern California. These cases, therefore, are in confirmation of early views on this subject. It is only in the remaining two cases where the facts seem to contradict the broad conclusion above mentioned, and where decay appears to have set in at points where, owing to the depth below grade line and below summits, the pipe must have been full practically all the time. These are the two cases quoted by the author; and it is fortunate that for one of these cases, at least, some information is now at hand. This information has been obtained through the assistant engineer on the original construction, who has been in direct charge of the repairs, and, therefore, it may be looked upon as of unusual reliability. It is to be regretted that neither the writer, for reasons previously stated, nor the author, appears to be in a position to furnish reliable data regarding the second case referred to, and it is hoped that such data may yet be at hand and be presented before the author closes his discussion. Mr. Henny.

With the experience gained, it now behooves engineers to study it closely, and determine whether it furnishes sufficient basis to justify a radical modification of previous views.

During the 10 to 11 years' service of the pipe it appears that 11% of all staves have been renewed, and 5½% of the line has been reconstructed. On the profile, Fig. 1, the locations of the reconstructed portions of the line are indicated by arrows. It will be seen at a glance that all these arrows are in close proximity to summits and within 50 ft. of the nominal hydraulic grade line. No reconstruction has been required on the long sections of pipe where the pressure has exceeded 50 ft. To that extent, at least, the pressure has had an effect upon the preservation of the wood; which is a salient and important fact, not in complete harmony with the series of facts or rather conclusions presented by the author. Whether it warrants the conclusion that the protection afforded by pressures exceeding 50 ft. has been sufficient, not only to obviate reconstruction, but to prevent decay, depends upon the present condition of the staves under such circumstances. This is a crucial point, in regard to which no satisfactory information has been furnished.

In view of the generally favorable experience with this class of pipe, under conditions of constant pressure and protection from evaporation, direct and conclusive evidence is required to upset previous views to the extent now advocated by the author; and, until such evidence is presented, the writer cannot agree to the sweeping

Mr. Henny. character of the author's conclusions, and takes exception notably to Conclusion 1, unless qualified as to the degree of pressure, and to Conclusions 2, 4 and 6, because they are not fully supported by the information submitted.

Why light pressures have generally been a satisfactory protection to the shell of a wooden pipe, and why, in the case of the Astoria pipe, a different experience has been had, is an interesting phase of the question, into which the author has not entered.

Decay, being a growth of fungus, is clearly communicable, and it may well be considered that the soil in a primeval forest, such as is traversed by the Astoria pipe line, containing decaying woody material, the accumulation of ages, may have produced this exceptional result.

With the experience gained, it may be concluded that, under such conditions and in a moist climate, evaporation from the surface is less to be feared than contact with soil, and that better results would have been obtained if at least the light-pressure portions of the pipe had been constructed above ground.

Increased knowledge of this character should lead to a determination of the conditions under which certain classes of construction may be considered safe and lasting, and under which they can be used with confidence; and this confidence will be the greater because of a more perfect understanding of the proper limitation.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## WORKS FOR THE PURIFICATION OF THE WATER SUPPLY OF WASHINGTON, D. C.

### Discussion.*

BY MESSRS. FRANCIS F. LONGLEY, WILLIAM C. WOODWARD, GEORGE M. KOBER, THEODORE A. LEISEN, W. L. BUTCHER, J. P. A. MAIGNEN AND D. C. HENNY.

Mr. Longley.

FRANCIS F. LONGLEY, JUN. AM. SOC. C. E. (by letter).—The first year of operation of the filtration plant described in this admirable paper by Messrs. Hazen and Hardy, has brought to light some unexpected facts regarding the typhoid fever conditions in the District of Columbia; facts which at first sight seemed most unfortunate, but which in the end may lead to a clearer knowledge regarding the epidemiology of typhoid fever in this and other cities.

The writer came to Washington to take charge of the laboratories of the filtration plant when it was first put in operation, in the summer of 1905. From the first, certain facts seemed to be evident, in the study of the unfiltered Potomac water. The numbers of bacteria varied with the quantity of turbidity in the water. After a rain, the numbers were very high. As the turbidity following the rain subsided, the numbers of bacteria decreased also, until after a prolonged period of dry weather, when the turbidity had reached its minimum, the number of bacteria in the water was remarkably low. For a period of 40 days in May and June, 1906, and another period of 13 days in September, 1906, all the daily samples of water applied to the filters showed bacterial counts of less than 100 per c.c.

* This discussion (of the paper by Allen Hazen and E. D. Hardy, Members, Am. Soc. C. E., printed in *Proceedings* for September, 1906) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

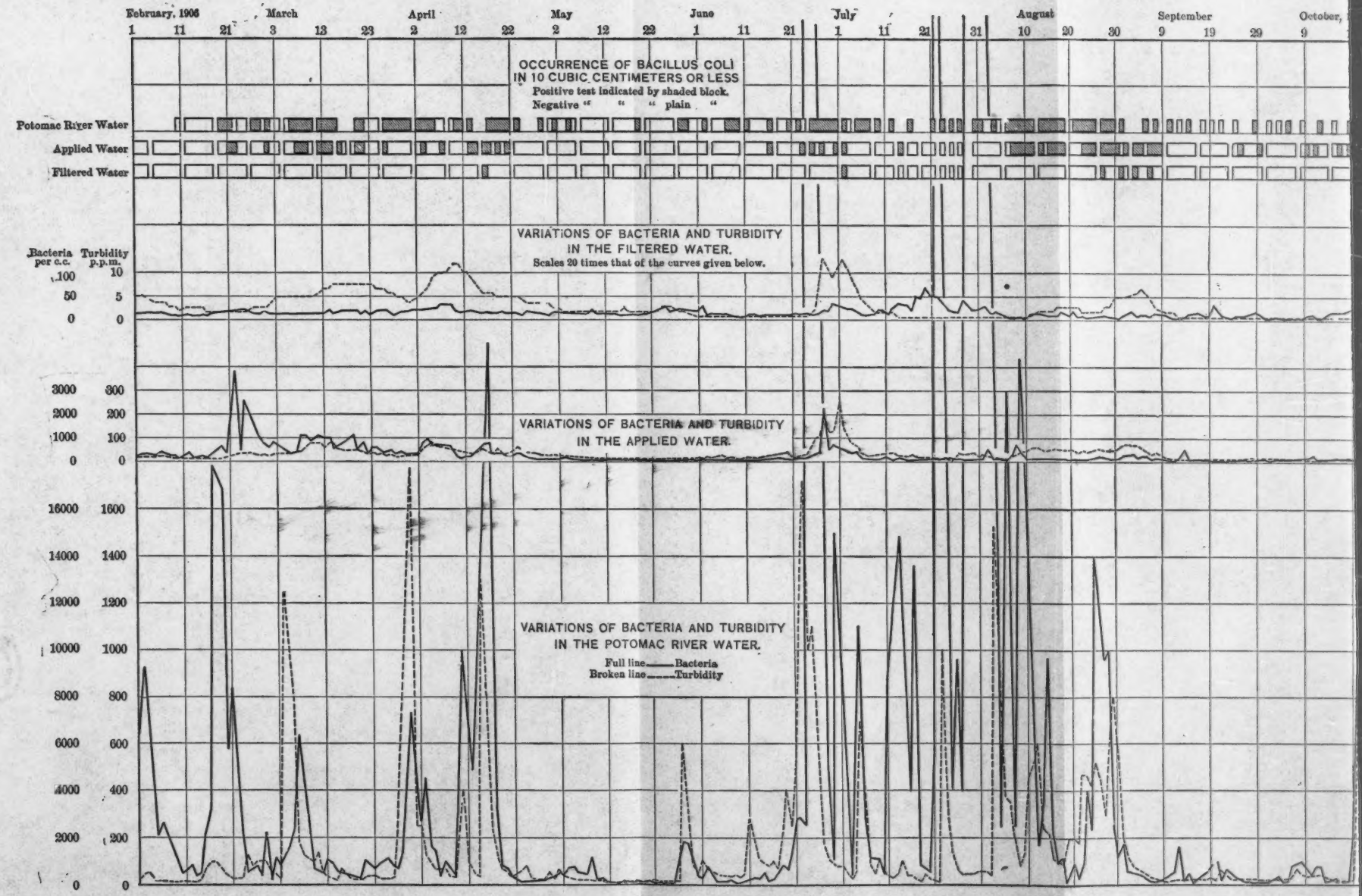
Mr. Longley. An examination of the results of tests for *B. Coli* also shows some significant facts. Of all the daily samples examined from the applied water, only 11% show the presence of *B. Coli* in 1 c.c., and only 27% in 10 c.c. When the bacterial count is at its lowest, the *Colon Bacillus* may not be detected for weeks at a time, and it is most often present when the water has a high bacterial count during the period of high turbidity following a rain. This variation of bacteria and turbidity, and also the presence of *B. Coli,* are shown on Plate CXIX.

The inference to draw from these facts is that by far the greater part of the bacterial content of the Potomac water, as it flows into the Washington Aqueduct system, comes from surface washings, clay, soil, manure from the fields, and all kinds of organic and inorganic matter. It is quite evident that constant sewage pollution is not present in appreciable quantity.

The authors give a tabulated statement of the population upon the water-shed above Washington, from which it may be seen that the danger to the community from drinking even the unfiltered water is much less than at Lawrence, or Albany, or Philadelphia, which cities have urban populations on their water-sheds many times as great. There is no intention of arguing that the unfiltered Potomac water is a safe water for domestic use. All unprotected surface waters are subject to specific infection from time to time, and this one is certainly not exempt, as is shown by the close relation traced in 1890 between typhoid fever in Cumberland, Md., and in Washington, and reported by Dr. George M. Kober, of Washington, before the International Medical Congress at Berlin.

The authors have referred briefly to the satisfactory sanitary quality of the filtered water. With regard to the numbers of bacteria in the filtered water, as determined by standard methods, there is small room for improvement. More significant than the direct reduction of numbers of bacteria in the process of filtration is the exclusion, more or less complete, of sewage organisms. This is truly the fundamental function of a filter; and in attaining this end it is often much simpler—and almost universal practice—to use, as a criterion of the sanitary efficiency of a filter, the reduction in the numbers of bacteria on the assumption that that reduction will likewise be a measure of the decreased risk from pathogenic organisms having their origin in sewage. The routine work of the laboratory of the Washington filtration plant has included careful tests for *Bacillus Coli communis,* the most typical of the sewage organisms, and in Table 7 is given a summary of the results of these tests.

In considering the effect of filtered water upon the public health, the significance of the occasional occurrence of *B. Coli* becomes of some importance. Table 8 indicates the presence of *B. Coli* in per-


February, 1906
March
April
May
June
July
August
September
October,
1 11 21 3 13 23 2 12 22 2 12 22 1 11 21 1 11 21 31 10 20 30 9 19 29 9
OCCURRENCE OF BACILLUS COLI
IN 10 CUBIC CENTIMETERS OR LESS
Positive test indicated by shaded block.
Negative " " " plain "
Potomac River Water
Applied Water
Filtered Water
VARIATIONS OF BACTERIA AND TURBIDITY
IN THE FILTERED WATER.
Scales 20 times that of the curves given below.
Bacteria per c.c.
Turbidity p.p.m.
100 10
50 5
0 0
3000 300
2000 200
1000 100
0 0
VARIATIONS OF BACTERIA AND TURBIDITY
IN THE APPLIED WATER.
16000 1600
14000 1400
12000 1200
10000 1000
8000 800
6000 600
4000 400
2000 200
0 0
VARIATIONS OF BACTERIA AND TURBIDITY
IN THE POTOMAC RIVER WATER.
Full line..... Bacteria
Broken line..... Turbidity

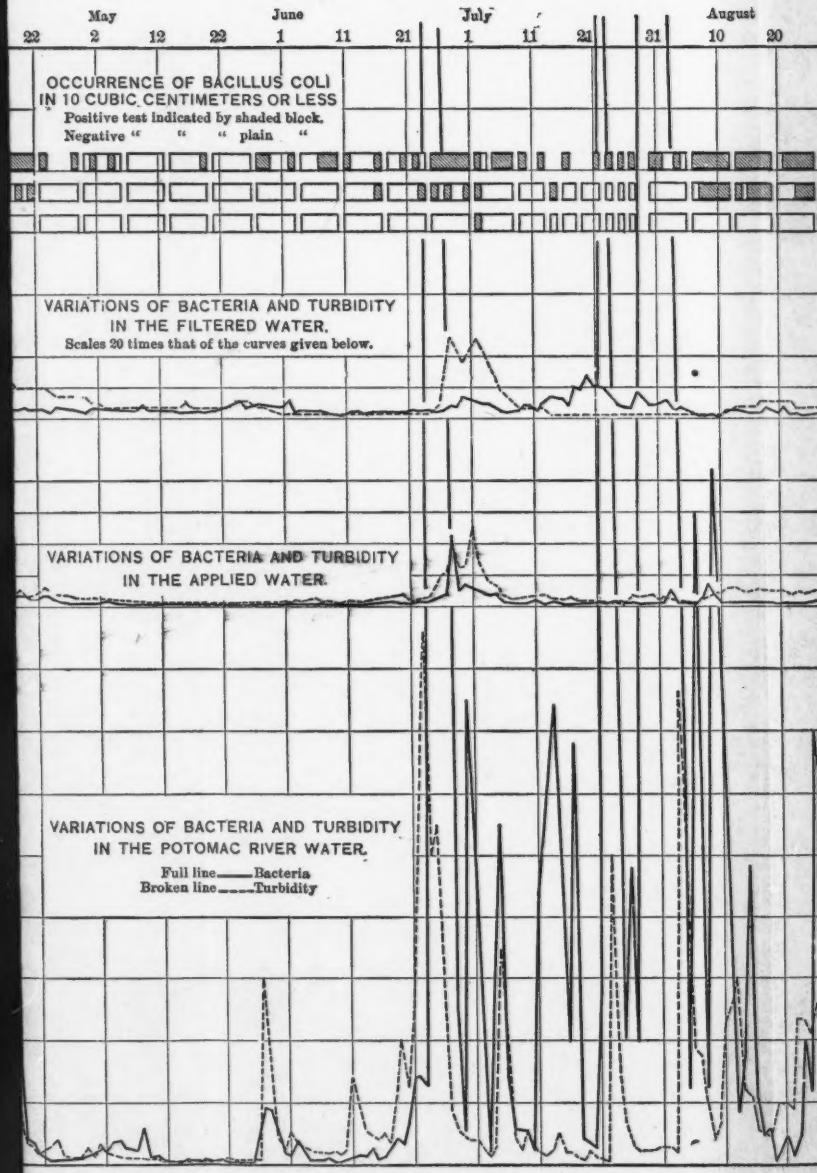
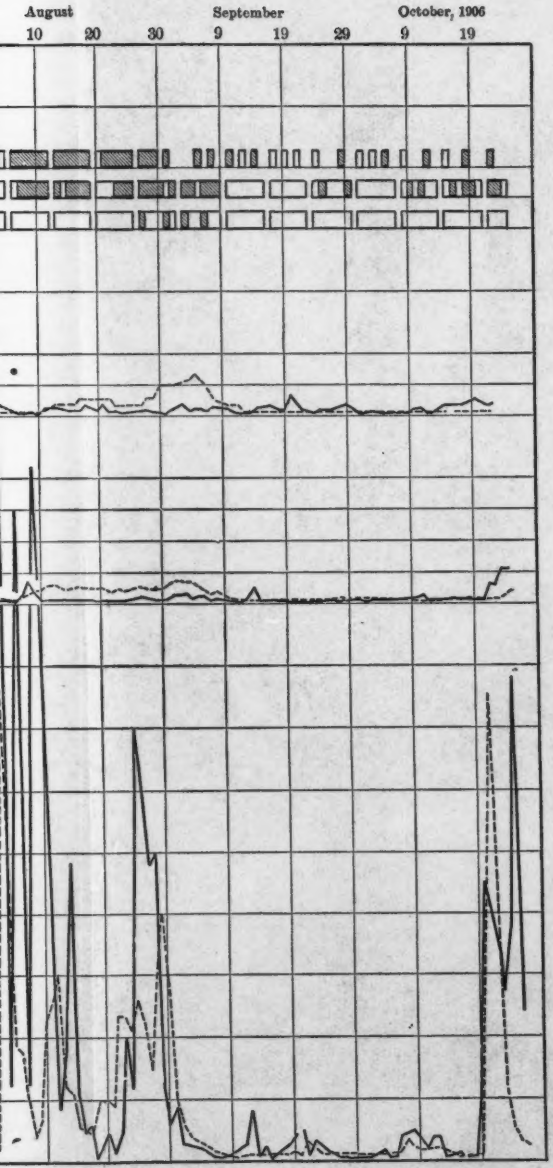

May
June
July
August
22
2
12
22
1
11
21
1
11
21
31
10
20
OCCURRENCE OF BACILLUS COLI
IN 10 CUBIC CENTIMETERS OR LESS
Positive test indicated by shaded block.
Negative " " " plain "
VARIATIONS OF BACTERIA AND TURBIDITY
IN THE FILTERED WATER.
Scales 20 times that of the curves given below.
VARIATIONS OF BACTERIA AND TURBIDITY
IN THE APPLIED WATER.
VARIATIONS OF BACTERIA AND TURBIDITY
IN THE POTOMAC RIVER WATER.
Full line——Bacteria
Broken line- - - -Turbidity

PLATE CXIX.
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LONGLEY ON
WATER FILTRATION.



centages of total numbers of samples of filtered water examined, for several water supplies. Mr. Longley.

TABLE 7.—SUMMARY OF RESULTS OF TESTS FOR *Bacillus Coli*.

| | | Total samples examined. | Number positive. | Percentage positive. |
|---|---|---|---|---|
| Great Falls or Dalecarlia Inlet | 10 c.c. | 164 | 71 | 43 |
| | 1 c.c. | 164 | 45 | 27 |
| | $\frac{1}{10}$ c.c. | 164 | 27 | 17 |
| Dalecarlia Outlet | 10 c.c. | 211 | 97 | 46 |
| | 1 c.c. | 211 | 55 | 26 |
| | $\frac{1}{10}$ c.c. | 211 | 20 | 9 |
| Georgetown Reservoir | 10 c.c. | 177 | 58 | 33 |
| | 1 c.c. | 177 | 34 | 19 |
| | $\frac{1}{10}$ c.c. | 177 | 9 | 5 |
| Washington City Reservoir. (Applied water) | 10 c.c. | 242 | 66 | 27 |
| | 1 c.c. | 242 | 26 | 11 |
| | $\frac{1}{10}$ c.c. | 242 | 3 | 1 |
| Filtered-Water Reservoir | 100 c.c | 148 | 26 | 18 |
| | 10 c.c. | 244 | 11 | 4 |
| | 1 c.c. | 244 | 5 | 2 |
| | $\frac{1}{10}$ c.c. | 93 | 0 | 0 |
| Tap water from various parts of city | 10 c.c. | 171 | 8 | 5 |
| | 1 c.c. | 171 | 3 | 2 |
| | $\frac{1}{10}$ c.c. | 59 | 0 | 0 |

TABLE 8.—PERCENTAGE OF SAMPLES SHOWING THE PRESENCE OF *Bacillus Coli*.

| | *Bacillus Coli* in: | | | |
|---|---|---|---|---|
| | 100 c. c. | 50 c. c. | 10 c. c. | 1 c. c. |
| Lawrence, Mass., 1905 | 57.9 | ..... | ..... | 5.0 |
| Philadelphia, Pa., 1905: | | | | |
| Upper Roxborough Plant | ..... | 18.0 | ..... | ..... |
| Lower Roxborough Plant | ..... | 26.0 | ..... | ..... |
| Belmont Plant | ..... | 34.0 | ..... | ..... |
| London, England, 6 months ending April 30th, 1906, Thames filtered waters | 17.9 | ..... | 8.5 | 1.9 |
| Washington, D. C., 10 months ending October 1st, 1906, Potomac filtered water | 17.0 | ..... | 3.0 | 1.6 |

The effect of filtration upon the water supply, as measured by the improvement in the public health, of all these cities but Washington, and of many others, is too generally known to need any comment. The tests to determine the effect of filtration upon a water are of such a nature as to exclude the probability of serious error in arriving at the percentage of reduction of bacteria and the elimination of *B. Coli* from the effluents of filters.

Mr. Longley.

In view of the excellent results obtained, as shown by the laboratory examinations, it was expected that there would be a reduction of the death rate from typhoid fever in the District of Columbia, following the improvement of the supply. The diagram, Fig. 17, will show that this reduction has not occurred.

That the District of Columbia has not an enviable position, in this regard, is shown by Table 9, compiled from the mortality reports of the United States Census.

TABLE 9.—ANNUAL AVERAGE NUMBER OF TYPHOID DEATHS PER 100 000 POPULATION, FOR THE FIVE YEARS, 1900 to 1904, INCLUSIVE.

| City. | Deaths. | City. | Deaths. |
|---|---|---|---|
| Pittsburg, Pa. | 137.6 | San Francisco, Cal. | 28.2 |
| Allegheny, Pa. | 103.4 | Buffalo, N. Y. | 28.0 |
| Columbus, Ohio. | 65.8 | Scranton, Pa. | 23.3 |
| Washington, D. C. | 62.8 | Boston, Mass. | 22.4 |
| Cleveland, Ohio. | 58.7 | Detroit, Mich. | 21.9 |
| Louisville, Ky. | 58.5 | Paterson, N. J. | 21.7 |
| Cincinnati, Ohio. | 55.8 | Providence, R. I. | 21.3 |
| Philadelphia, Pa. | 49.6 | Newark, N. J. | 20.1 |
| Kansas City, Mo. | 48.8 | Fall River, Mass. | 19.8 |
| Indianapolis, Ind. | 48.2 | New York, N. Y. | 19.2 |
| Denver, Colo. | 47.0 | Omaha, Nebr. | 19.1 |
| Memphis, Tenn. | 45.5 | Syracuse, N. Y. | 18.7 |
| New Orleans, La. | 44.9 | Jersey City, N. J. | 18.6 |
| Minneapolis, Minn. | 44.7 | Milwaukee, Wis. | 17.1 |
| New Haven, Conn. | 44.5 | Worcester, Mass. | 16.0 |
| St. Louis, Mo. | 39.3 | Rochester, N. Y. | 14.9 |
| Baltimore, Md. | 36.5 | St. Paul, Minn. | 14.8 |
| Toledo, Ohio. | 34.7 | St. Joseph, Mo. | 13.9 |
| Chicago, Ill. | 29.7 | | |

The condition of the filtered-water supply has already been set forth. In addition to this, there is another supply which is of interest in this discussion. In the District of Columbia there are more than 100 public wells, most of which are classed as "shallow wells," having depths varying from 7½ to 40 ft. These wells are very freely used, especially during the summer months, when the high temperature of the city supply makes it unpalatable. These wells have all been examined, and, on the strength of the analyses, they fall naturally into two groups, "deep wells" and "shallow wells," quite different in character. The water from the deep wells is quite generally of good sanitary quality. Chemical and bacteriological examinations are not at all necessary to show that the water from the shallow wells is bad. A great many of the wells are very close to the sewers; in fact, on the drawings in the office of the Sewer Department, some of the wells seem to be directly on the line of the sewers. The ground-water level is practically everywhere below the

Mr. Longley.

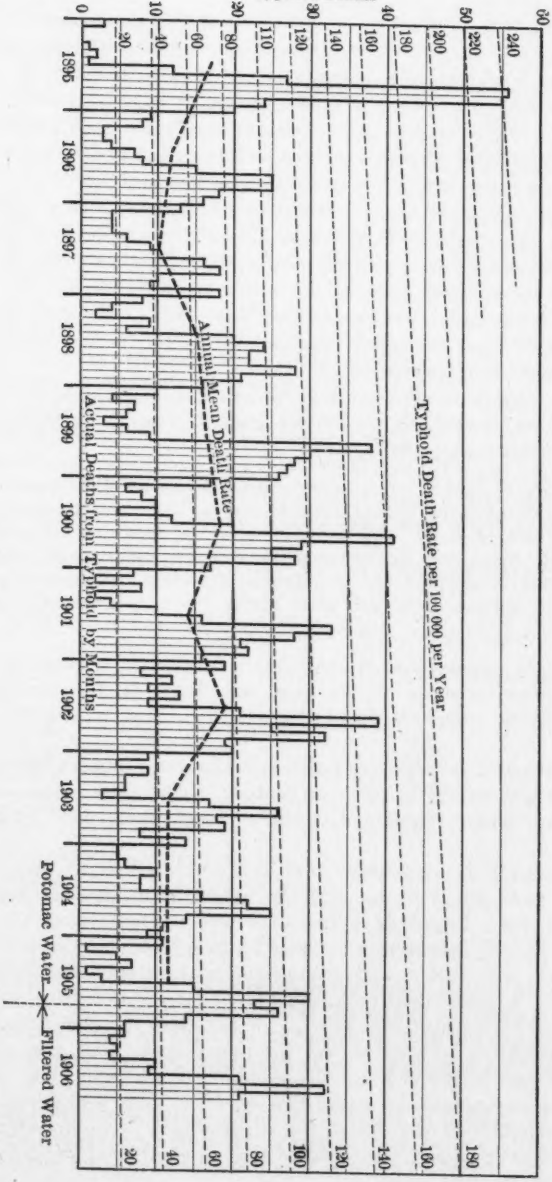



FIG. 17.

Mr. Longley. level of the sewers, so that any leakage must be from the sewers to the ground-water.

This condition of the shallow wells is brought out very clearly by the examination of the water. Chlorines and nitrates are all extremely high, and the *Colon Bacillus* was found in 25% of the wells. In view of these results, and more especially in view of the close proximity of wells and sewers, wastes, and drainage of all kinds, it is safe to say that none of these shallow wells can be used continuously without being a menace to the health of the District.

There are, of course, a number of other factors to be considered as affecting the typhoid death rate. The milk supply is to be regarded with some suspicion, and with good reason, as some 10% of the cases during 1906 have been traced quite definitely to milk infection. It is hoped to remedy this part of the situation during the coming winter by legislation providing for better and more extensive inspection service.

The ice supply of Washington is probably no worse than the average. To quote from a classic work by Professors Sedgwick and Winslow on the subject of ice:

"The general result of human experience, the absence of epidemics of typhoid fever traced conclusively to ice, the fact that cities like New York, Lowell, and Lawrence have used ice of polluted streams, and have yet maintained low death rates from typhoid fever, all tend to support the conclusion at which we have arrived, namely, that natural ice can very rarely be a vehicle of typhoid fever."

Barring the possibility of some extraordinarily unsanitary conditions existing in some of the local ice factories, the ice supply may probably be regarded as having no important relation to this question.

The question of infected shell fish is probably of small importance in this problem, as the maximum typhoid death rates come at the time of year when the consumption of raw shell fish is at its minimum.

It can readily be conceived that contaminated fruit and vegetables may have much to do with the presence of typhoid fever in Washington. An apple or a head of lettuce may pass through devious routes and through many questionable hands before reaching the consumer, who eats it with wonderful faith in the cleanly habits of his kind. A great deal of garden truck and small fruit sold in the markets of Washington is grown not far from the city. Typhoid fever has prevailed in this region for many years, and may easily take this course in keeping up the endemic condition. The writer has made examinations of quantities of fruit and vegetables, and has found suspicious organisms in surprisingly large numbers at times. It does not seem improbable that a good deal of infection

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might be spread by this means, going to all classes, in all parts of the city, at just the time of year when these commodities are most plentiful in the market.

The colored population of Washington offers a good field for study of conditions which favor the spread of the disease by contact. The relative typhoid fever mortality among the white and colored population has been the subject of some study. The colored people as a class are more ignorant of the principles of hygiene than are the whites. Their circumstances and environment are less favorable to health. They are more careless in their personal habits. As a race, they are more susceptible to disease than the whites; this statement is substantiated by the fact that the health reports of the District of Columbia show greater death rates among the colored population in twenty-six out of thirty-one causes of death cited. And perhaps not the least important is the fact that they are much more gregarious than the white population, which facilitates the spread of communicable diseases among them.

In Table 10 are given the typhoid death rates of the white and colored populations of several cities. These are based on a total population equivalent to about 4 000 000 colored people for one year, and a much larger number of white people. Other figures are at hand, less reliable, but all substantiating those given herewith.

TABLE 10.—TYPHOID DEATH RATES PER 100 000 POPULATION PER YEAR.

| City, etc. | White. | Colored. | Ratio, colored to white. |
|---|---|---|---|
| Cincinnati, Ohio | 47.2 | 94.0 | 1.99 |
| Washington, D. C. | 60.5 | 88.4 | 1.46 |
| Baltimore, Md. | 42.1 | 57.1 | 1.36 |
| Charleston, S. C. | 76.0 | 94.8 | 1.25 |
| New Orleans, La. | 47.5 | 58.7 | 1.24 |
| Richmond, Va. | 34.6 | 37.9 | 1.10 |
| Memphis, Tenn. | 37.7 | 40.0 | 1.06 |
| AND FROM THE REPORT OF THE 12TH CENSUS: | | | |
| The United States, (entire area, for the year 1900) | 43.0 | 73.9 | 1.50 |
| The United States (registration area, for the year 1900) | 32.4 | 69.5 | 2.15 |

The figures in Table 10 show in every case a higher typhoid death rate among the colored than among the white population, and it is reasonable to suppose that the influence of this higher rate will be felt to a certain degree among the white population with whom they mingle.

Of course, the white population in itself is subject to infection from this cause, too. As long as people remain untaught as to the necessity for, and the most efficient means of, proper disinfection, the

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progress of the disease from this cause will be inevitable. And there is probably little doubt that a great deal of the typhoid fever everywhere is carried in this way, from one person to another, in some cases directly, but more often by ways too devious and complicated for even the most painstaking observer to trace.

In considering the factors that may have an influence upon the presence of typhoid fever in the District of Columbia, an examination of the vital statistics of certain other cities may bring out information of some value. A number of cities have been studied. They were chosen with regard for their similarity to Washington in a good many respects. Leaving out of consideration the large floating population which is of necessity a part of the capital city, Washington is distinctively southern. It has a larger colored population than any other city in the country. Most of these cities have the large open markets typical of the south; and most of them are exposed to the dangers from many polluted wells within their limits. As to their public water supplies, five of them, Philadelphia, Baltimore, Richmond, Cincinnati, and New Orleans, are like Washington in having surface supplies subject to pollution. The other two—Memphis and Charleston—have artesian supplies which, as far as they go, may probably be assumed to be above reproach.

For purposes of comparison, the typhoid deaths, for each month and for each city, have been reduced to death rates per 100 000 population per year, based on the average population during the period covered by the records used. This seasonal distribution is shown in the diagram, Fig. 18. The figures are equivalent to observations upon a population of 20 000 000 people for a period of one year.

The most obvious characteristic of all but two of these curves is the similarity to the annual temperature curve, as has been pointed out by Professors Sedgwick and Winslow in a paper on the seasonal prevalence of typhoid fever. Their general observation was that, in cities having comparatively pure public water supplies, this curve of seasonal distribution of typhoid fever was similar to, and followed a little after, the temperature curve; while in cities having badly polluted public water supplies, the curve was very irregular, bearing no constant relation to the temperature, and having in some cases several maximum points in a year.

On this assumption, these cities may be grouped in two classes: Cincinnati and Philadelphia have curves typical of polluted supplies, and the other cities have the characteristic curves following the temperature curve. That Philadelphia has had a badly polluted supply is conclusively proven by the remarkable reduction in the typhoid death rates in those parts of the city served by the new filtered supply. The evidence is strong, too, that Cincinnati's supply is badly polluted. The irregularity of the curves for these two cities is much more evident from an examination of the curves for successive years than from the mean curve shown in Fig. 18.

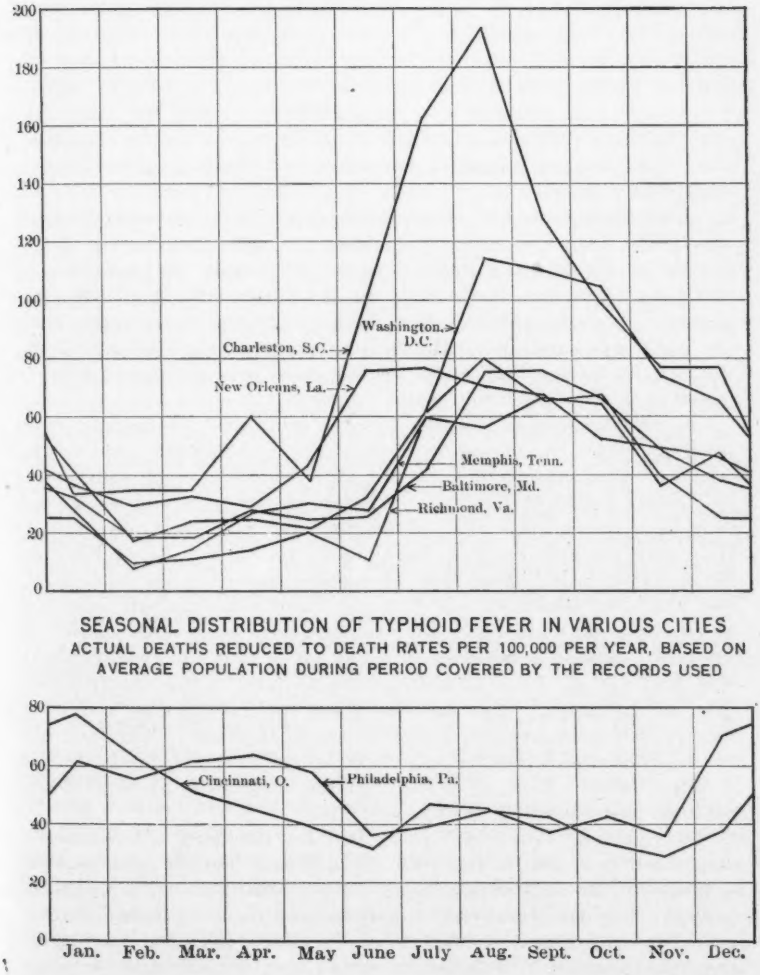

200
180
160
140
120
100
80
60
40
20
0
Charleston, S.C.
Washington, D.C.
New Orleans, La.
Memphis, Tenn.
Baltimore, Md.
Richmond, Va.
SEASONAL DISTRIBUTION OF TYPHOID FEVER IN VARIOUS CITIES
ACTUAL DEATHS REDUCED TO DEATH RATES PER 100,000 PER YEAR, BASED ON AVERAGE POPULATION DURING PERIOD COVERED BY THE RECORDS USED
80
60
40
20
0
Cincinnati, O.
Philadelphia, Pa.
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.

FIG. 18.

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On the other hand, two of the cities of the other group have artesian public supplies which may probably be considered above criticism, from a sanitary point of view. The others have surface supplies subject to pollution, but in none of them are the conditions such as to make the water supply necessarily a serious and constant menace. Therefore, in view of the similarity of conditions in these cities, and of the curves of seasonal distribution of this disease; and in view of the dissimilarity to the two cities of the other group, is it not readily conceivable that the factors tending to produce typhoid fever in the six cities of this class should be much the same; and that the case of Charleston, with its public water supply eliminated from the question, might be the same as of Washington, only in an exaggerated form?

A peculiar feature of these curves suggests an unanswered question. The lowest monthly death rates, in the cities having curves typical of "polluted supplies," come in August, September, and October, when the death rates in the other group of cities are highest. If it be assumed that these two cities simply have these two factors in addition to the factors common to all the cities, why do they not have a high curve during these late summer months, in addition to their "polluted water" curve?

In seeking reasons for the present prevalence of typhoid fever in Washington, in amount as great as in previous years, one suggestion has been made which is full of possibilities, and which time will either prove or disprove. What might the typhoid death rate have been during this year if the filtration plant had not existed? It is quite conceivable that the typhoid due to the use of Potomac River water might have been eliminated more or less completely, and that this beneficial effect might have been entirely obscured by an abnormal quantity of the disease due to some other cause. It has been common experience in many cities that the typhoid death rate does not go down to bed-rock immediately after the improvement of the supply. The decrease often extends through a term of years, and a comparatively slight abnormal increase in the first year due to other causes might easily cover up the decrease due to the use of better water. This, of course, is mere conjecture, as no evidence has been found tending to corroborate it.

To sum up, Washington has had an excellent filtered water supply for more than a year; the typhoid rate has not been reduced in the least; the milk supply is known to be the cause of some of the typhoid; considerable suspicion may be cast upon the many shallow wells, and also upon market products eaten in their raw state; undoubtedly much infection is spread by contact, and probably some by the agency of flies. These and other possible factors are so mingled that the problem is a very complicated one even to those most familiar with all the conditions.

These various factors are touched upon in only a very superficial

manner. They are not dismissed as settled, in any degree, as many of them are conditions about which the writer has but imperfect knowledge. The problem is being investigated at length by competent authorities, and their report, when made public, will throw much more light on the subject than does this discussion. It is greatly to be hoped that the results of the investigation will point the way for definite remedies, and at the same time give a better insight into the conditions under which typhoid fever exists in many of the cities of the United States. Mr. Longley.

WILLIAM C. WOODWARD,* M. D. (by letter).—In the present situation and in this paper the writer has a special interest, as he was one of the representatives of the medical profession of Washington in the efforts that led, in the first place, to the determination to purify the water supply, and in the second, to the use for that purpose of the slow sand process rather than the chemico-mechanical method. Lack of proper technical training prevents him from discussing the paper directly, and he will merely submit a few queries and a few facts which may lend point to the discussion by others. Dr. Woodward.

In the first place, it is stated that the sand used at Washington was required by the specifications to have a greater freedom from fine particles than the sand used with such satisfactory results elsewhere. This, in effect, means that it was desired that the interspaces between the grains should be larger, and that the filter was designed with that end in view. Why, then, when the excessively fine particles suspended in the applied water find their way further into the sand layer than is usually the case, should it be attributed to the peculiar composition of the applied water, instead of to the unusual character of the sand layer?

Again, it is stated that the water reaching the filters has been settled to an unusual extent, and that no filters of the same type as those at Washingon have been used in America with water settled anything like so much. This, it is said, is the cause of that peculiar condition of the applied water which is responsible for the penetration of suspended matter so deeply into the sand, and a project is submitted for the installation of apparatus for adding a coagulant to the water and for transforming one of the reservoirs into a more efficient sedimenting basin, in order to overcome the difficulty. The question naturally arises, why is it necessary to permit such excessive sedimentation to continue? Are not the reservoirs provided with by-passes, and cannot the extent to which the water is sedimented be accurately controlled within reasonable limits by such by-passes? And if such by-passes have been used and the unsedimented water has been applied to the filters without satisfactory results, why attribute to the excessive sedimentation the conditions complained of?

* Health Officer, District of Columbia.

Dr. Woodward. Moreover, has it been demonstrated that, as a matter of fact, the penetration of the fine clay into the sand layer for a distance of 2 or 3 in. does harm? Apparently, it renders it necessary to remove more sand at each scraping, but does it not proportionately diminish the frequency of the scrapings? Have not the freshly scraped filters been found as efficient as any other freshly scraped filters? And has not the bacterial efficiency of the Washington filters been equal to that of any filters where the sediment penetrates the sand less deeply?

It is stated that the use of a coagulant would result in conditions more nearly approaching what are termed normal, because the suspended matter in the applied water would be reduced in quantity and changed in character, being in the form of a loose "floc," capable of being stopped at the surface layer. If the excessive sedimentation of the applied water is now responsible for the penetration of the suspended matter to an unusual depth into the sand, and such penetration is objectionable, is anything to be gained by still further reducing the quantity of suspended matter by using a coagulant? And is it so certain that the quantity of matter suspended in the water when the surface of the sand layer is reached would be reduced? The quality of the raw water is subject to variations which are neither infrequent nor closely limited to their range, and the quantity of water used also fluctuates from time to time. Under such conditions, can the chemistry and mechanics of coagulation and sedimentation be controlled so as unerringly to throw out of suspension a quantity of sand and clay in excess of the quantity of precipitate that will reach the sand layer?

And finally, is it so certain that the cost of operating the system with the use of coagulants would not be materially greater than it is now? At the very beginning there is an outlay of $105 000 for the necessary apparatus for admitting the coagulant and for remodeling one of the reservoirs to meet the changed conditions. And if, to the interest and sinking fund based on this investment, there is added the cost of labor and material, the total annual cost of the coagulating works would be very considerable. What evidence is there to show that this would be offset by a reduction in the cost of cleaning the filters? Would the collection of the precipitate on the surface of the sand permit such an extension of the length of the runs as the authors of the paper anticipate? The arresting of this flocculent precipitate on the very surface of the sand might result in a denser layer, it would seem, one more nearly impervious to water, and thus necessitate more frequent cleaning, and increase the total cost, even though it might not be necessary to remove the sand to quite as great a depth each time.

After all, the only reason for adding a coagulant seems to be to

guard against the appearance of any turbidity in the effluent; and, as a medical man and a sanitarian, the writer does not take the question of turbidity at all seriously. He cannot agree with the authors of the paper that the suspended matter or turbidity is that quality of the water that makes the greatest impression upon the public. It is granted, of course, that the turbidity might be so disproportionately high, in comparison with the morbidity and mortality rates from water-borne diseases, that it might attract more attention than the latter; but, as between a high morbidity and mortality from water-borne diseases and a turbidity merely correspondingly high, the public would be impressed in the long run more strongly by the sickness and death than by the imperfect transparency of the water. As an official of a municipal government that is striving hard to better the physical condition of the people under its care, the writer questions the propriety of the expenditure of public funds solely for the removal of turbidity as long as there are so many other outlets for the money that promise more definite sanitary and social returns. A city without a public bath-house, without a playground worthy of the name, with miles of marshland on its very borders, without a sanitarium for the treatment of indigent consumptives in the early stages of the disease, with alleys crying earnestly to be opened up—such a city, particularly when there is no public complaint of the muddiness of its water supply, is not in a position to expend $100 000 and more to establish a clarification system, and thousands of dollars annually for its maintenance. Dr. Woodward.

The possible effect of the use of aluminum sulphate or other coagulant on public health is not considered herein. Too little is known about public health—and too little about private health, either, for that matter—to speak dogmatically concerning it. From the experience of millions of millions of people, extending over thousands of years, it is known, however, that pure water which has not been treated with a coagulant is a safe beverage, and those who seek in any given instance to introduce a coagulant into a public water supply must bear the burden of proof to show that without its use pure water cannot be obtained, and that from its use no harm can come, not even through human frailty, which is not less than the danger that will result solely from the omission of the chemical.

All this is written in no spirit of criticism of the filter or of its work, nor for the purpose of suggesting any impracticable remedies for dangers real or fancied. The writer's purpose has been to point out the fact that there is no substantial evidence that the system of filtration endorsed by the medical profession for use at Washington cannot be made to yield perfectly satisfactory results, from the standpoint of bacterial efficiency and of turbidity. The writer knows of no evidence that indicates even that the very plant that has been

Dr. Woodward.

constructed has not given satisfactory results when gauged by the standard of bacterial efficiency, and the only evidence that has ever come to his knowledge that it has not yielded an effluent satisfactorily clear has come from those concerned in the operation of the plant, who appear to have been dissatisfied at times because they were unable to attain the high standard of brilliancy in the effluent that they have set before them. The public seems to be satisfied.

If the writer were asked, however, what practical benefit had resulted during the year that the filters have been at work, he would be compelled to say that filtration had done but two things: First, it has given a drinking water which has been clear enough to satisfy any reasonable person; no complaint of turbidity has been heard, there has been no ground for such a complaint. Second, the filtration plant has stood between the people of Washington and the inhabitants of the basin of the Upper Potomac River to safeguard them against possible infection from that source; if, however, the filtration plant has actually prevented a single case of typhoid fever or of other water-borne disease, evidence of it has not been discovered. It is not stated that it has not saved many from such diseases, for it is not known how many might have been afflicted if the filtration plant had not been in operation, but if it has prevented any cases whatsoever the writer has not found any evidence of that fact. The design or operation of the filters are not being blamed; from the bacteriological records relating to the operation of the plant, it would be unsafe for anyone to do so without direct evidence.

The writer is being forced to the conclusion that all were mistaken in blaming the public water supply for the prevalence of typhoid fever in Washington. It may be, however, that the boiling of drinking water and the use of bottled waters for drinking, which had become rather common practices after the real extent of the prevalence of typhoid became known, had eliminated a considerable part of the water-borne typhoid fever before the filtration plant was put into operation, for about July, 1903, there occurred a sudden drop in the morbidity and mortality rates, and the lower rates then established have continued ever since. In any event, the writer is unable to formulate any hypothesis to explain the present excessive incidence of this disease in the District of Columbia that is consistent with the accepted theory as to the causation of typhoid fever, *viz.*, that typhoid fever is due to the ingestion of certain bacilli which have come through either urine or feces from a patient suffering from that disease. But no efforts have been abandoned for the prevention of this disease along lines already laid down: the closing of public wells as rapidly as circumstances justify, the abolition of box privies, and the improvement of the milk supply; and it is expected that the filtration of the water supply will be continued

until the end of time. It is to be hoped that the discussion of this paper may point to some remedy which will afford more speedy relief than is promised by any or all the measures heretofore undertaken and still in progress. Dr. Woodward.

GEORGE M. KOBER,* M. D. (by letter).—The writer has read with much pleasure this excellent paper, and has considered the question which naturally concerns the sanitarian most, *viz.*, the bacterial efficiency of the filtration system and its effect upon lessening the typhoid fever rate; and here one is at once confronted with the remarkable fact that, while the bacterial efficiency of the Washington plant is all that could be desired, the average number of bacteria in the effluent being only 29 as compared with 4 900 in the raw water, no apparent decrease in the number of typhoid fever cases has resulted during the first year of its practical operation. This would seem to indicate that the Potomac water is either not as important a factor in the prevalence of typhoid fever as heretofore assumed, or that seasonal and telluric influences have been exceptionally favorable for a large crop of typhoid this year, and that the situation would have been infinitely worse had it not been for the efficiency of the filtration plant. The latter explanation should be accepted until further observation compels a different view. A decrease of 50% in the typhoid fever rate was confidently expected, as the writer believes that about 50% of the cases are water-borne, and this, too, in spite of the fact that he was the first to point out the agency of flies in the spread of the disease; about 15% of all cases are brought to the city from mountain resorts by returning vacationists; milk produced in typhoid-ridden districts is probably responsible for 15% of the cases, and the remainder, about 20%, may be spread through the agency of flies, personal contact, the consumption of raw oysters raised in sewage-polluted oyster beds, or the eating of strawberries, radishes, celery, lettuce or other vegetables which have been contaminated by infected night-soil. The writer has not had the time or opportunity to examine into the typhoid situation elsewhere, but has suggested, to those now engaged in the investigation of the subject, the desirability of making such a comparison. He is not disposed to exclude the "drinking-water theory" altogether, or to regard the amount of typhoid fever now remaining as purely "residual," because all the other factors have operated in former years, and there is no reason to assume that the milk supply is any worse now than it was ten years ago, for, as a matter of fact, since the enactment of a pure-milk law in 1895, there has been a decided decrease in the death rate of children under five years of age; indeed, the percentage of deaths of children under one year has been reduced from 26.94 in 1893 to 18.36 in 1905, due solely to the diminution Dr. Kober.

* Georgetown University, Washington, D. C.

Dr. Kober. of the number of deaths among children, and not to an increase in the total number of deaths. The gradual reduction in the number of box privies, from 30 000 in 1871 to about 4 000 in 1905, should also have resulted in a reduction of the danger from flies in the transmission of the germs. The same may be said of public wells, which have been reduced from 171 in 1895 to 102 in 1905; the number of private wells, however, is still a matter of conjecture. As long as public wells are permitted to exist at all, it is difficult to estimate the part they have in the dissemination of typhoid fever; they are promiscuously used, and, as they are located in a polluted subsoil, they must be regarded as a constant source of danger, and, upon general principles, should be condemned. The gradual elimination of public wells appears to be an extremely conservative policy, because wells which from time to time are declared infected have passed the scrutiny of the chemist and bacteriologist for years before. The Rivers Pollution Commission,* more than 25 years ago, advised the closing of all the wells in London but three which were exceptionally placed.

To the student of epidemiology, the situation, on the whole, is extremely interesting and perplexing, and indicates that there is yet much to be learned regarding the causes and spread of typhoid fever; but the writer has not ceased to hope that the typhoid situation in Washington will clear up, as it did in Berlin.

In 1872 Berlin and Washington were alike in primitive municipal methods of sanitation. Without adequate distribution of the water supply, the larger part of their population was dependent upon public and private wells. Without sewerage systems, both were alike supplied with makeshifts for the disposal of human excreta and waste waters. The unpaved streets were the common receptacle of garbage, ashes and house sweepings, and along the gutters the surface and house drainage were conducted to the neighboring watercourses. Since Berlin began its system of sanitary improvements, completed in 1890, at a cost of 59 000 000 marks for a pure and ample water supply and 42 500 000 marks for the construction of sewers, the typhoid fever death rate has fallen from 143 per 100 000 of its inhabitants in 1872 to 4 in 1894; and the general death rate has fallen from 32.9 per 1 000 in 1875 to 16.4 per 1 000 in 1904, while the death rate from typhoid fever in Washington is still six times as great as that of Berlin, yet the general death rate has been reduced from 28.08 in 1875 to 19.20 in 1905, which is encouraging, considering the mixed character of the population.

In 1875 only 57 houses in Berlin were connected with the sewers, and the general death rate was 32.9 per 1 000. In 1885 there were 15 895 houses with sewer connections, and the death rate was 24.4;

* Sixth Report, p. 284.

the Washington rate was 24.9. In 1895 the Berlin death rate was 19.8, and the Washington death rate was 20.5. Dr. Kober.

In conclusion, the hope is expressed that the recommendation of the authors for the installation of a coagulating process in periods of great turbidity, may be speedily acted upon, and that the general installation of meters will lessen the waste of water and thus permit of a slower rate of filtration. These recommendations cannot fail to increase the efficiency of the plant.

THEODORE A. LEISEN, M. AM. SOC. C. E. (by letter).—This paper is extremely interesting, and makes a valuable addition to the literature on filtration of public water supplies. The reference to the proposed preliminary treatment of the water opens up a subject not as generally familiar as that of the final or ordinary treatment, by slow sand filtration. This question has occupied a share of the writer's attention for the past few years, in connection with the proposed filtration of the water supply of Wilmington, Del., and, while financial, legal and other complications have been the means of preventing or delaying the actual construction of the contemplated works, the delay has afforded time and opportunity to carry out some work on experimental lines which, in the end, may prove beneficial to the cause. Mr. Leisen.

The principal object of the experimental work was the determination of the utility of preliminary treatment of the water preparatory to final filtration by the slow sand system: First, in establishing its value in increasing the efficiency of the sand filters; and second, in reducing the cost of operation.

The experiments were along mechanical lines, in contradistinction to chemical treatment, where a coagulant is required.

The experimental plant consists of two preliminary filters, each 4 ft. wide by 11 ft. long, having an effective area of $\frac{1}{1000}$ acre, and three slow sand filters, having an area equivalent to $\frac{1}{6000}$ acre. The preliminary filters receive the raw water directly from Brandywine Creek (which is the source of supply for the city). Two of the final sand filters receive the pre-filtered water from the preliminary filters, while the third takes the water directly from the creek. The slow sand filters are constructed in the usual manner, and call for no special comment.

Three types of preliminary filters have been used in the experiments. Filter No. 1, generally known as the Maignen filter, was constructed on lines advocated by J. P. A. Maignen, Assoc. Am. Soc. C. E. It consists of a lower strainer course of large gravel or broken stone, above which is placed about 14 in. of coke, and on top of this, 20 in. of sponges, which are slightly compressed, and held down by a wooden rack. The water is introduced from below, through a perforated pipe, filtering upward, and overflowing at the top.

Mr. Leisen.

Filter No. 2 was constructed on lines similar to those of mechanical filters, sand being the filtering medium. A series of pipes with perforated strainers serves to carry off the filtered effluent, and also to introduce air and water for washing purposes.

Filter No. 3 is similar in general design to Filter No. 1, except that charcoal is substituted for coke, and the water is taken in at the top and flows downward, discharging through the strainer system at the bottom.

From the information obtained previous to commencing these experiments, it was believed that the sponge filter (No. 1) would operate for a period of from 6 to 12 months without undue loss of head, or excessive clogging, but the experience of the first few months demonstrated conclusively the falsity of this hypothesis. Within a month after starting, springs formed, materially interfering with the efficiency, and a reversal of the current (the only means then provided for partially washing) did not completely remedy the evil. At the end of two months the loss of head due to clogging was so great that the sponge had to be removed and washed.

In an effort to provide more efficient means for washing this filter, air wash-pipes were introduced early in February, since which time the work of this filter has been uniformly satisfactory. It has been deemed expedient to limit the loss of head to 12 in., and, under the conditions existing since February, during which time there have been periods of excessive turbidity, the periods between washings have averaged about 30 days. The rate of filtration is about 50 000 000 gal. per acre per 24 hours.

Filter No. 2 was operated for several months, but it was found to clog up so rapidly—with a consequent loss of head and decrease in rate—and to require such constant attention and such an excessive quantity of wash water, that it was thought advisable to abandon it, as unsuited to the requirements.

Filter No. 3 was in operation about 5 months, and, while it showed a very high efficiency at the start, with slight loss of head, it was found to be unsatisfactory in the end, as a mud layer several inches thick, which formed on top of the sponges, broke through at intervals and allowed the water to course through, practically nullifying the efficiency. After repeated efforts to overcome this difficulty, without success, the filter was abandoned.

Filter No. 1 has removed as little as 33% of turbidity, and occasionally as much as 100%, but the average since February, when the air-wash was introduced, has been 65% reduction of turbidity, while the average bacterial reduction has been about 65 per cent. For brevity, all detailed statements of bacteria and turbidity are omitted.

Mr. Leisen.

The influence of this preliminary treatment on the final slow sand filters may be summarized in the statement that no appreciable difference is found in the filtered effluents from the creek water and from the pre-filtered water, in so far as the final bacterial efficiency is concerned, but the final clarification is improved by pre-filtration. Its influence on the economy of operation, however, is more marked, as the evidence so far obtained has demonstrated that the quantity of water passed through the slow sand filters for each run is doubled by the use of the preliminary filter; or, in other words, in the filters fed with pre-filtered water, the period between scrapings has been twice as long as that between scrapings of those receiving creek water.

The advantage attained in prolonging the duration of runs in the slow sand filters insures both greater economy and increased uniformity, with a consequent increase in general efficiency, for, as every disturbance of the sand beds produces deterioration in the quality of the filtered effluent, so any treatment that minimizes the number of scrapings will evidently tend toward higher average results.

It may be assumed that the preliminary treatment referred to herein is simply a rapid system of sedimentation, and its economic value will depend, first, upon a comparison of the cost of construction and maintenance of a sedimentation basin and a preliminary filter of equal effective capacity; and second, upon the combined cost of construction and maintenance of a slow sand filter with and without the preliminary filters. Both these considerations are questions which have to be determined separately in each individual case.

The data, upon which the foregoing is based, are too meager, and cover too short a period to warrant any conclusive deductions, but are here presented as a subject for discussion, pending further experiments.

Mr. Butcher.

W. L. Butcher, Assoc. M. Am. Soc. C. E. (by letter).—Developments in sanitary engineering are taking place so rapidly that a knowledge of the merits and faults of the latest completed works must be considered absolutely necessary to the engineer striving to keep abreast of the times in this branch of the profession.

Perhaps the subject of most immediate usefulness to the designer of water purification plants is that relating to the hydraulics of the sand-handling apparatus. The writer has seen no account of similar experiments conducted elsewhere.

These investigations were a part in the development of one of the most interesting features of the works; namely, the installation for lessening the cost of removing, cleaning and replacing the sand. The authors' comparison of labor expenses at Washington with

Mr. Butcher. those at older plants, while instructive, does not show the actual saving in total cost brought about by mechanical means. For such a comparison with older plants, where nearly the whole expense may be charged to the cost of labor, some account must be taken of the capital invested to make the saving possible.

Estimating from the figures in the paper, it would appear that about 20 or 25 cents per cu. yd. should be added for interest on the capital invested. Presumably, also, the wages of the laborers are much less than at the more northern works. The cost of handling sand at Philadelphia is stated to be $1.20 per cu. yd., the latest annual reports of the Board of Public Works being given as the authority. From the 1905 report, the writer computes the average expense as 83 cents per cu. yd.

In the case of such large filters, with their many acres of sand to be scraped at frequent intervals, might it not be economical and practicable to install some sort of mechanical scraper? This might take the form of a light traveling crane operated by an electric motor on rails attached to the piers. An inclined and adjustable scoop about 1 ft. wide would convey the sand to a detachable hopper holding about 1 cu. yd., or the quantity collected in one passage from end to end of the bed. On reaching the end of the filter the hopper would be run directly over an ejector, and be detached and replaced by an empty receptacle for the return trip.

The trend of present practice seems to be away from the use of wholly automatic devices for regulating the flow of the effluent—such as are used at Philadelphia—the opinion being, apparently, that, as the rate of change of loss of head is so slow in the case of slow sand filters, the value of automatic regulating devices is not commensurate with the difficulties involved in their construction. This, of course, is not the case with mechanical filters.

The results of the first few months of operation have emphasized the value and necessity of investigations previous to construction. Fortunately, in the case of the Washington plant, no considerable outlay is required to bring the works into such shape as to conform more closely with the recommendations derived from the preliminary investigations.

Mr. Maignen. J. P. A. MAIGNEN, ASSOC. AM. SOC. C. E.—In describing the construction of the walls of the pure-water reservoir the authors conclude thus: "A lighter steel-concrete wall, or a buttressed concrete wall, might have been used, with some saving of expense." The writer would like to know why this was not done.

The system of compensating orifices intended to prevent "that part of the filter nearest the outlet to operate at a rate much higher than intended," is commendable. The speaker has used it at Lower Roxborough and elsewhere, and it works well in comparatively small

filters, operated at a high and nearly constant rate of filtration; but, in a filter unit with an area of 43 560 sq. ft., with rates of filtration varying from 1 000 000 to 4 000 000 gal. per acre per day, the conditions are different. The orifices made for the 4 000 000-gal. rate are too large for the 1 000 000-gal. rate. What evidence is there that the orifices computed for the high rate will act satisfactorily for the low rate? Mr. Maignen.

The stone and gravel underdrains are 12 in. in thickness—the first layer being 7 in. and the other two 2½ in. each. This comparatively thin layer of gravel might be sufficient for small filters, carefully handled; but, for units of 1 acre the speaker would prefer deep layers of underdrain materials.

The quality of the sand used appears to be satisfactory. It is of small size, as compared with the Philadelphia sand. The method used for preparing it at the bank is quite interesting. Nothing that can be done for producing a good filter sand is to be accounted as extravagant. If economies are to be made, they are not to be tried on the materials that do the work. They are to be sought in the general design of the plant and in the accessories.

The water is pumped directly from the Washington City Reservoir to the filters, without passing through any compensating reservoir. The authors, in accounting for this omission, say "there is no space available * * * on the site selected, all of which is required for the filters." If a compensating reservoir with a capacity of 3 000 000 or 4 000 000 gal. had been really thought necessary, space could easily have been found. The sand courts, for instance, could have been reduced in size; or preliminary filters could have been installed, with the object of increasing the rate of final filtration and reducing the number of final filters. This direct pumping appears to be a departure from what is understood as the best practice.

The authors say:

"The pure-water reservoir is arranged so that when it becomes full it will back up water against the filters and reduce the rate of filtration automatically."

Is this right?

The general practice in operating slow sand filters is to disturb the filtering medium as little as possible. So-called automatic mechanical devices of every description have been designed with a view of insuring a constant rate of filtration, but, in general, hand-regulation has been found the safest. The filter attendant, at first, keeps the outlet valves partly closed, and then, as the friction in the upper portion of the sand bed increases, which phenomenon is indicated by the loss of head, he opens the valve little by little, day after day, endeavoring all the time to maintain the rate of filtration as constant as possible so as not to disturb the filtering material. An

Mr. Maignen. inattentive filter attendant who opens the valves too much or too little in the middle of a run, and thus brings about a variation in the rate of filtration, will not retain his position very long. The automatic reduction and acceleration of the rate of filtration, as the water rises and falls in the Washington pure-water basin, commended by the authors, does, every day, and several times a day, precisely what the filter attendant is instructed not to do.

The outlet valves which lead the filtered water into the pure-water reservoir are placed at an elevation of about 2 ft. from the bottom of the filters (the top of the 20-in. outlet valve is 2 ft. 8 in. above). This is a feature which is somewhat unusual, and does not appear to be desirable. Taken in combination with the backing up of the water from the reservoir, this feature must have a tendency to keep the sand layer, below and above the outlet valve, in a loose condition. This loose state of the sand may perhaps account for the "abnormally long period between scrapings," and the soiling of the sand "to a most unusual depth." The authors think that this penetration is due to the fact that the water is so well settled before it reaches the filter that it "does not contain particles of a size to form at the surface of the sand the sediment layer usually obtained in the operation of sand filters." This defect, if it should really exist, could be easily overcome by putting in the water those particles which are said to be wanted; these can be procured without coagulation.

The authors describe at some length the sand-washing process, and the illustrations show the very picturesque sand bins. These are certainly an improvement on the old sand courts, but the speaker thinks that the bins are as unnecessary as the courts; both are likely to be ignored in future filter plants in favor of sand-washing systems, in or about the filter bed, with the immediate return of the sand to its working place. The speaker does not like to see dirty water going into the bin with the sand. He also objects altogether to the ejector system, mainly because it wastes or separates the finer from the coarser particles of sand, and thus gradually reduces the efficiency of the whole.

The authors do not say anything about preliminary filtration. They insist on coagulation. The speaker maintains that, as the average turbidity of the water in the Washington City Reservoir does not exceed 30 parts per million, it is possible to deal with it by physical methods. Coagulation was strongly objected to, for hygienic reasons, when the matter came up originally before Congress. The speaker now objects to it for financial reasons. The authors say it will cost 50 cents per million gallons for all the water treated throughout the year. Preliminary filtration, with such modifications in the final filters and their operation as might be found necessary,

would not add anything to the total cost of filtration. The cost of the installation and operation of preliminary filters would be more than compensated by economies in the operation of the final sand filters and by the higher efficiency obtained. Mr. Maignen.

As allusion has been made to the prevalence of typhoid fever at Washington, it may be of interest to know the influence which filtration has had on this disease at South Bethlehem. Table 11 is the month record of typhoid and enteric fever for the four months of the year in which it is most prevalent—January, February, March, and April—during the last four years:

TABLE 11.—TYPHOID AND ENTERIC FEVER AT SOUTH BETHLEHEM, PA. NUMBER OF CASES AND DEATHS.

| Month. | 1903. | | 1904. | | 1905. | | 1906. | |
|---|---|---|---|---|---|---|---|---|
| | Cases. | Deaths. | Cases. | Deaths. | Cases. | Deaths. | Cases. | Deaths. |
| January | 17 | 4 | 5 | 5 | 1 | 0 | 1 | 0 |
| February | 6 | 14 | 6 | 5 | 1 | 0 | 1 | 0 |
| March | 68 | 7 | ? | 5 | 0 | 0 | 0 | 0 |
| April | 66 | 12 | 8 | 2 | 0 | 0 | 4 | 0 |
| Totals | 157 | 37 | 21 | 17 | 2 | 0 | 6 | 0 |

| Totals for 1904 and 1905, before the filter plant was installed.* | | Totals for 1905 and 1906, after the filter plant was installed. | |
|---|---|---|---|
| Cases. | Deaths. | Cases. | Deaths. |
| 178 | 54 | 8 | 0 |

* The filter plant was placed in operation in November, 1904.

D. C. HENNY, M. AM. SOC. C. E. (by letter).—The writer visited the Washington filtration plant, both before and after its completion. He believed that pure utilitarianism had been carried to its extreme in the western part of the United States, on works built for quick profits and then only in remote localities, but confesses that, when visiting the completed Washington filtration plant, he was struck by the total absence of any attempt at architectural treatment, except as to the pumping station and the depressed entrances to the filters. Mr. Henny.

By far the most conspicuous parts of the plant are the elevated, concrete sand bins. Whether these could have been built in a depressed condition and the washed sand could have been returned to the filters by utilizing the pumping plant and pipe lines already

Mr. Henny. provided, is a matter which the authors have undoubtedly considered, but possibly only from an economic standpoint. As built, these sand bins are elevated, and, aided by their great number, they attract attention from afar.

Large smooth surfaces of concrete are never attractive in appearance, being unrelieved by joints and often discolored in unsightly ways. There are fine examples, however, of simple, artistic and comparatively cheap treatment of concrete surfaces. In this instance, no attempt appears to have been made to relieve the barren monotony.

Much may be written about the justification of the expenditure of public money for architectural effect, in connection with works of public necessity, and differences of opinion in regard thereto will always exist. If such expenditure is justified anywhere, however, it is believed to be in this instance, on prominent monumental structures built by the United States Government within the confines of the City of Washington.

# MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

## JUSTIN BURNS, Assoc. M. Am. Soc. C. E.*

DIED NOVEMBER 14TH, 1905.

Justin Burns was born in Watertown, New York, on July 28th, 1870. He was of Irish parentage. He received his early education in the Watertown public schools, and was graduated from the High School with honor when eighteen years of age. He then won a scholarship in Cornell University in a competitive examination, and received his degree of Civil Engineer in 1892.

His first work was with J. D. and T. E. Crimmins on the construction of the Third Avenue Cable Railroad, in New York City. From April, 1893, to 1897, he was Assistant Engineer with the Chicago and West Michigan Railroad, engaged in designing, inspection and construction work in the bridge department. In 1897, Mr. Burns returned to New York City, and was appointed Assistant Engineer under the Commissioner of Street Improvements of the 23d and 24th Wards, and upon the formation of the greater City of New York, in 1898, he entered the service of the newly formed Department of Bridges. He prepared designs for several viaducts and bridges in the Borough of The Bronx, and was in charge of construction of the City Island Bridge connecting City Island with the mainland at Pelham Bay Park, of the Westchester Avenue Bridge over the Bronx River, of the Brook Avenue Tunnel on the Port Morris Railroad, and of a number of smaller works.

From May, 1898, to February, 1899, Mr. Burns served with the First Regiment, United States Volunteer Engineers, in Porto Rico, as Sergeant Major, and later as Second Lieutenant. On his return from the war he resumed his work in the Department of Bridges, and in May, 1900, was appointed Assistant Engineer with the Rapid Transit Railroad Commission of the City of New York, and had charge of work from the City Hall to Canal Street, including the construction of the City Hall Loop, a heavy concrete arch under City Hall Park, and the single-track crossing under the four-track main line on Park Row.

He resigned from the Rapid Transit service in October, 1902, to go with the American China Development Company, of which William Barclay Parsons, M. Am. Soc. C. E., was Chief Engineer.

* Memoir prepared by W. J. Boucher and J. G. Theban, Associate Members, Am. Soc. C. E.

His work was on the construction of the Canton-Hankow Railway, first as Division Engineer of the Sam Shui Division and later as First Assistant Engineer, and he was in direct charge of the location and construction of the railroad in South China. When this work was suspended, in March, 1904, he returned to New York City and entered the employ of the Rapid Transit Construction Company as Resident Engineer in charge of viaduct construction.

In March, 1905, he was made Engineer-in-Charge of the reconstruction and extension of the street railway system of Memphis, Tenn., by the firm of Ford, Bacon and Davis, and, while in that city, was chosen Vice-President of the Memphis Engineering Society. In October, 1905, while on a short visit to his home in Watertown, he contracted typhoid fever, and died on November 14th, 1905.

Mr. Burns was a fine musician and an accomplished linguist. He was also interested in literary work, and, besides contributing articles on technical subjects to the engineering press, lectured before several American colleges on railroad and bridge work. His highest aim was to extend the field of his labors, and he often made personal sacrifices in order to broaden his experience. His professional work was marked by a natural ability which was enhanced by unremitting study and unflagging industry. His superiors esteemed him as an able, conscientious and reliable man; his colleagues and subordinates remember his generous help and encouragement, which often inspired them to conquer difficulties. All his friends admired the gentle kindness that accompanied his noble strength of character. His untimely death cut short a career that gave promise of honor and success. In religion, he was a Roman Catholic, and he was unmarried.

Mr. Burns was elected an Associate Member of the American Society of Civil Engineers on April 6th, 1898.

# PROCEEDINGS

OF THE

# AMERICAN SOCIETY

OF

# CIVIL ENGINEERS.

(INSTITUTED 1852.)

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VOL. XXXII. No. 10.

DECEMBER, 1906.

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NEW YORK 1906.

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# American Society of Civil Engineers.

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E. KUICHLING.

*Term expires January, 1908:*
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*Secretary*, CHARLES WARREN HUNT.

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*Directors.*

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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Vol. XXXII. DECEMBER, 1906. No. 10.

# AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

# PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

## SOCIETY AFFAIRS.

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## MINUTES OF MEETINGS.

### OF THE SOCIETY.

**December 5th, 1906.**—The meeting was called to order at 8.40 P. M.; Vice-President Emil Kuichling in the chair; Charles Warren Hunt, Secretary; and present, also, 127 members and 22 guests.

The minutes of the meetings of November 7th and 21st, 1906, were approved as printed in the *Proceedings* for November, 1906.

A paper by J. A. Ockerson, M. Am. Soc. C. E., entitled "The Atchafalaya River: Some of Its Peculiar Physical Characteristics," was presented by the Secretary, who also read communications on the subject from Messrs. T. G. Dabney, F. M. Kerr, and H. B. Richardson. The paper was also discussed by G. H. Thomson, M. Am. Soc. C. E.

A paper, by Leonard M. Cox, M. Am. Soc. C. E., entitled "The Naval Floating Dock—Its Advantages, Design and Construction," was also presented by the Secretary. Written discussions from Messrs. J. R. Baterden, C. Colson, C. H. Peabody, and Geo. B. Rennie were read by the Secretary.

The Secretary reported that, in compliance with the direction of the meeting of November 7th, he had canvassed the ballot on the appointment of a Special Committee "To collect such information as may be obtainable on the present and prospective status of the adoption of the Metric System in the United States, and to collate and systematize such information and promulgate it to the Society in form of reports from time to time," and had reported the result to the Board of Direction as follows:

| | | |
|---|---|---|
| Total number of ballots received..... | 1 071 | |
| Not entitled to vote..... | 15 | |
| Total votes counted ..... | | 1 056 |
| In favor ..... | 936 | |
| Against ..... | 107 | |
| Voted blank ..... | 12 | |
| Without signature ..... | 1 | |
| | | 1 056 |

This result authorizes the appointment, by the Board, of the Special Committee.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Edward Harding Barnes, Grand Rapids, Mich.
Thomas Webster Barrally, Tonawanda, N. Y.
Robert Calvin Brown, Pittsburg, Pa.
Alex Dow, Detroit, Mich.
Narayana Pranatarti Hara Aiyar, Madras Presidency, India.
Zac Ellis Knapp, London, England.
Manuel Maria Mendiola, Ciudad Juárez, Chihuahua, Mexico.
John Pierce-Hope, La Paz, Bolivia.
Ely Morgan Talcott Ryder, New Haven, Conn.
Lawrence William Wells, Terrell, Tex.
Edward Nathan Wood, Chicago, Ill.

As Associate Members.

Robert Lee Alexander, Hawley, Minn.
Louis Russell Ash, Kansas City, Mo.
Asa White Kenney Billings, Havana, Cuba.
Clinton Talcott Bissell, Brooklyn, N. Y.
John Henry Burgoyne, Jr., Galeton, Pa.
John Hull Decker, Atlantic City, N. J.
Isaac De Young, Sault Ste. Marie, Mich.
Arthur Herbert Diamant, New York City.
Frederick Bernhardt Duis, Wellsburg, W. Va.
Oliver Cromwell Edwards, Jr., Troy, N. Y.
George Harrison French, St. Louis, Mo.
Charles Edward Gilman, San Francisco, Cal.
Alfred Hanson Hartman, Baltimore, Md.
James Henry Haylow, Memphis, Tenn.
William Christian Hoad, Lawrence, Kans.
Conway Robinson Howard, Ashland, Ky.
Charles Chase Hurlbut, New York City.
James Edgar Jenkins, New York City.
George Whitney Kinne, Highland, N. Y.
George Stewart Minniss, Buffalo, N. Y.
John Hampden Randolph, Jr., Baton Rouge, La.
Harry Ashton Roberts, Pocatello, Idaho.
Charles Victor Seastone, West La Fayette, Ind.
Francis Libby Sellew, Yuma, Ariz.
Joseph Grundy Shryock, Philadelphia, Pa.
Charles Vernon Smith, New York City.
Harry Bronson Snell, Brooklyn, N. Y.
Ellis Clark Soper, South Pittsburgh, Tenn.
Norman Alfred Taylor, Troy, N. Y.
Nathan Davis Whitman, Jackson, Mich.
Abraham Underhill Whitson, Eastport, N. Y.

As Associate.

David Walker Brooks, Columbus, Ohio.

The Secretary announced:

The transfer of the following candidates by the Board of Direction, on December 4th, 1906:

From Associate Member to Member.

Shirley Carter, Norfolk, Va.
John Herbert Gregory, Columbus, Ohio.
Samuel Alexander McCoy, Hawley, Minn.
George Aymar Taber, Brooklyn, N. Y.

The election of the following candidates by the Board of Direction:

AS JUNIORS.

On May 1st, 1906:

ALTON PHILIP TRUFANT, Springfield, Mass.

On October 2d, 1906:

BYRON ELLSWORTH WHITE, Utica, N. Y.

On December 4th, 1906:

CHESTER SALISBURY ALLEN, Worcester, Mass.
JAMES RAMSEY BALDRIDGE, New York City.
RALPH HANEY BURKE, Lockport, Ill.
JAMES HARPER DUNCAN, Houlton, Me.
FRANK HASBROUCK EARLE, JR., Newark, N. J.
EARL QUERBACH, Sewickley, Pa.
WILLIAM WEST WILSON, New York City.

The Secretary announced the following deaths:

ARTHUR VAUGHAN ABBOTT, elected Junior, January 5th, 1881; Member, December 4th, 1901; died December 1st, 1906.

JOHN EUGENE CHENEY, elected Member, May 7th, 1884; died September 25th, 1906.

GEORGE BENSON NICHOLSON, elected Member, May 1st, 1878; died December 3d, 1906.

SAMUEL SPENCER, elected Member, September 2d, 1885; died November 29th, 1906.

BENNO ROHNERT, elected Junior, April 3d, 1889; died September 1st, 1906.

Adjourned.

**December 19th, 1906.**—The paper by James D. Schuyler, M. Am. Soc. C. E., entitled "Recent Practice in Hydraulic-Fill Dam Construction," is to be presented. Because of the necessity for going to press with this number of *Proceedings* in advance of this meeting, the publication of the minutes will be deferred until January, 1907.

## ANNOUNCEMENTS.

**The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.**

### MEETINGS.

**Wednesday, January 2d, 1907.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "The Necaxa Plant of the Mexican Light and Power Company," by F. S. Pearson and F. O. Blackwell, Members, Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for October, 1906.

**Wednesday and Thursday, January 16th and 17th, 1907.**—The Fifty-fourth Annual Meeting will be held. The Business Meeting will be called to order at 10 o'clock on Wednesday morning at the Society House. The Annual Reports will be presented, officers for the ensuing year elected, members of the Nominating Committee appointed, proposed amendments to the Constitution presented for action, and other business transacted.

Arrangements for the Annual Meeting have been placed in the hands of a committee composed of Messrs. William E. Belknap, George E. Gifford, and Chas. Warren Hunt, and a general programme will soon be issued.

**Wednesday, February 6th, 1907.**—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Lighthouse Construction in the Philippines," by Spencer Cosby, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for November, 1906.

**Wednesday, February 20th, 1907.**—8.30 P. M.—A paper entitled "Rainfall, and Run-Off in Storm-Water Sewers," by Charles Emerson Gregory, Assoc. M. Am. Soc. C. E., will be presented for discussion at this meeting.

This paper was printed in *Proceedings* for November, 1906.

## NOMINATING COMMITTEE.

The Constitution provides that, at the Annual Meeting of each year, seven Corporate Members, not officers of the Society, one from each of the geographical districts into which the Society is divided for this purpose, shall be appointed by the meeting, to serve two years. In consequence of the death of A. H. Zeller, Assoc. M. Am. Soc. C. E., it will be necessary to appoint two members for District No. 6.

The usual blank request for suggestions as to representatives of each district, for presentation to the meeting, has been mailed to Corporate Members.

## PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

**North of England Institute of Mining and Mechanical Engineers,** Newcastle-upon-Tyne, England.

**Society of Engineers,** 17 Victoria Street, Westminster, S. W., England.

**American Institute of Mining Engineers,** 99 John Street, New York City.

**Boston Society of Civil Engineers,** 715 Tremont Temple, Boston, Mass.

**Civil Engineers' Club of Cleveland,** 1200 Scofield Building, Cleveland, Ohio.

**Engineers' Club of St. Louis,** 3817 Olive Street, St. Louis, Mo.

**Engineers' Club of Philadelphia,** 1122 Girard Street, Philadelphia, Pa.

**Engineers' Society of Western Pennsylvania,** 803 Fulton Building, Pittsburg, Pa.

**Western Society of Engineers,** 1737 Monadnock Block, Chicago, Ill.

**Louisiana Engineering Society,** 604 Tulane-Newcomb Building, New Orleans, La.

**Engineers' Club of Central Pennsylvania,** Corner Second and Walnut Streets, Harrisburg, Pa.

**Engineers' and Architects' Club of Louisville, Ky.,** 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

**Teknisk Forening,** Vestre Boulevard 18–1, Copenhagen, Denmark.

**Société des Ingénieurs Civils de France,** 19 Rue Blanche, Paris, France.

**Svenska Teknologförenigen,** Brunkebergstorg 18, Stockholm, Sweden.

**Institute of Marine Engineers,** 58 Romford Road, Stratford, London, E., England.

**Midland Institute of Mining, Civil and Mechanical Engineers,** Sheffield, England.

**Sachsischer Ingenieur- und Architekten-Verein,** Dresden, Germany.

**Associação dos Engenheiros Civis Portuguezes,** Lisbon, Portugal.

**Pacific Northwest Society of Engineers,** 617–618 Pioneer Building, Seattle, Wash.

**Institution of Naval Architects,** 5 Adelphi Terrace, London, W. C., England.

**Memphis Engineering Society,** Memphis, Tenn.

**Oesterreichischer Ingenieur- und Architekten-Verein,** Eschenbachgasse 9, Vienna, Austria.

**The Junior Institution of Engineers,** 39 Victoria Street, Westminster, S. W., London, England.

**Institution of Engineers of the River Plate,** Buenos Aires, Argentine Republic.

**Sociedad Colombiana de Ingenieros,** Bogota, Colombia.

**Australasian Institute of Mining Engineers,** Melbourne, Victoria, Australia.

**Cleveland Institute of Engineers,** Middlesbrough, England.

**Civil Engineers' Society of St. Paul,** St. Paul, Minn.

**Koninklijk Instituut van Ingenieurs,** The Hague, The Netherlands.

**Rochester Engineering Society,** Rochester, N. Y.

## SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

# ACCESSIONS TO THE LIBRARY.

From November 14th to December 5th, 1906.

## DONATIONS.*

### RAILROAD CURVE TABLES

Containing a Comprehensive Table of Functions of a One-Degree Curve, with Correction Quantities Giving Exact Values for Any Degree of Curve; Together with Various Other Tables and Formulas, Including Radii, Natural Sines, Cosines, Tangents, Cotangents, etc., to Which is Added a Method of Finding Any Function of a Curve of Any Degree or Radius Without a Field Book. By R. S. Henderson. Cloth, 5 x 7 in., illus., 4 + 69 pp. New York, The Engineering News Publishing Co., 1906. $1.00 net.

Theoretical discussions have been omitted from this book, as it is intended only as a supplement to existing field books. The author states that the correction quantities given are original in that they are applicable to any function of a curve, and are independent of the central angle. The rectangle co-ordinates, $X$ and $Y$, are believed to be new. Extreme care has been taken with the computations, and the approximation of 5 730 ft. for the radius of a one-degree curve has not been used. The Contents are: Explanation of Terms; Use of Tables; Table I, Minutes in Decimals of a Degree and Length of a 1° Curve; Table II, Functions of a 1° Curve; Table III, Correction Quantities; Table IV, Curves Designated by Radius; Table V, Radii; Table VI, Natural Sines and Cosines; Table VII, Natural Tangents and Cotangents; Table VIII, Frogs and Switches; Table IX, Standard Rail Sections; Table X, Inches in a Decimal of a Foot; Table XI, Trigonometrical Formulas; Miscellaneous Formulas and Their Application; Appendix: Field Engineering Without a Field Book.

### HENDRICKS' COMMERCIAL REGISTER

Of the United States. For Buyers and Sellers. Especially Devoted to the Interests of the Architectural, Mechanical, Engineering, Contracting, Electrical, Railroad, Iron, Steel, Mining, Mill, Quarrying, Exporting and Kindred Industries. Fifteenth Annual Edition. Cloth, 10 x 8 in., illus., 62 + 1 275 pp. New York, Samuel E. Hendricks Co., 1906. $10.00.

This is an annual index of the above-mentioned industries, containing more than 350 000 names and addresses and upwards of 15 000 business classifications. It gives full lists, with names and addresses, of manufacturers of, and dealers in, everything used in the manufacture of material, machinery and apparatus for these industries. The contents are classified by subject, under which are given, in alphabetical order, the names and addresses of firms who deal in that particular article. There is an index of sixty-two pages.

### ELEMENTS OF SANITARY ENGINEERING.

By Mansfield Merriman, M. Am. Soc. C. E. Third Edition, Enlarged. Cloth, 9 x 6 in., illus., 250 pp. New York, John Wiley & Sons, 1906. $2.00 net.

While this volume is intended primarily for the use of engineering students, it is hoped that it may prove useful to municipal officers who have supervision of sanitary works, and to the general public as well. In the preface, the author states that greater prominence has been given to the fundamental principles necessary to secure a pure water supply or an efficient system of sewerage, than to the details of construction and operation. At the end of each chapter a series of exercises and problems is given in order to acquaint the student with the use of engineering indexes, books and journals. Since the publication of the first edition of this book in 1898, important advances in the methods of sewage disposal have been made, especially in the development of the septic tank, the contact-bed, and the sprinkling filter. These changes have made it necessary to rewrite the last chapter of former editions, and to divide it into two chapters, one treating of sewage disposal, and the other of the disposal of refuse and garbage. Changes have been made also in other chapters in order to bring them up to date, and an appendix has been added

*Unless otherwise specified, books in this list have been donated by the publisher.

giving information regarding a few of the most important works recently constructed or in process of construction. The number of pages has been increased from 222 to 252 and the number of exercises and problems from 121 to 158. The Contents are: Sanitary Science; Water and Its Purification; Water-Supply Systems; Sewerage Systems; Disposal of Sewage; Refuse and Garbage; Appendix. There is an index of six pages.

**TEXT-BOOK ON GEODESY AND LEAST SQUARES**

Prepared for the Use of Civil Engineering Students. By Charles L. Crandall, M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 10 + 329 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $3.00.

The author states that this book is the outgrowth of a course of lectures on geodesy, prepared for the instruction of students at Cornell University at a time when there was but little written in English on the subject outside of the United States Coast Survey reports. Field practice in geodetic, hydrographic and topographic surveying was introduced as part of the course, which practice furnished data for reduction, computation and mapping. The lecture notes were revised from time to time, and, in preparing them for publication, they have been elaborated to give them the character of a textbook, and revised in order to bring the work up to the latest and best practice. The material for the work was collected from such books as Clarke's Geodesy, Jordan's Vermessungskunde, Chauvenet's Method of Least Squares, Wright and Hayford's Adjustment of Observations, and the Reports of the Coast Survey Office. The Contents are: Part I, Geodesy: Introduction; Triangulation, Reconnaissance, Signals; Instruments and Observing; Base Line Measurement; Trigonometric and Precise Leveling; Figure of the Earth; Geodetic Positions; Determination of the Dimensions of the Ellipsoid. Part II, Least Squares: The Method of Least Squares; Theory; Application to Triangulation; Tables. There is an index of six pages.

**REINFORCED CONCRETE.**

Part I.—Methods of Calculation by Albert W. Buel. Part II.—Representative Structures; Part III.—Methods of Construction by Charles S. Hill. Second Edition, Revised and Enlarged. Cloth, 9 x 6 in., illus., 12 + 499 pp. New York, The Engineering News Publishing Company, 1906. $5.00 net.

The first edition of this work was published in 1904. In the preface of the present edition, as in that of the first, it is stated that the authors have in mind a treatise for designing and constructing engineers following the best and latest practice, and governed by conditions which prevail in America. Theoretical discussions have been omitted, and in their place have been supplied practical working formulas, examples of representative structures, and records of actual practice in the selection of materials and of methods of workmanship and construction. The book is divided into three parts: Part I dealing with the methods of calculation and the design of reinforced concrete; and Parts II and III dealing with the details of, and the methods used in, constructing various classes of reinforced-concrete structures. In order to bring the present edition up to date, the text has been carefully revised, and additions to the several chapters have been made. Appendices containing tests of beams and columns made by Professor Talbot, at the University of Illinois, and by the United States Government, at the Watertown Arsenal, have also been added. The Contents are: Economic Use and Properties of Reinforced Concrete; Beams and Theories of Flexure; Columns; Retaining Walls, Dams, Tanks, Conduits and Chimneys; Tests and Designs of Arches; Foundation Construction in Reinforced Concrete; Reinforced Concrete in Building Construction; Reinforced Concrete in Bridge and Culvert Construction; Examples of Reinforced-Concrete Conduit Construction; Examples of Reinforced Tank and Reservoir Construction; Examples of Reinforced-Concrete Retaining Walls, Dams, Chimneys, etc.; Material Employed in the Fabrication of Reinforced Concrete; Methods of Construction in Foundation Work; Methods of Construction in Building Work; Methods of Construction in Bridge Work; Methods of Construction in Conduit Work; Facing and Finishing Exposed Concrete Surfaces. There is an index of seven pages.

**UNIVERSAL DICTIONARY OF MECHANICAL DRAWING.**

By George H. Follows. Cloth, 8 x 11 in., illus., 60 pp. New York, The Engineering News Publishing Company, 1906. $1 net.

The object of this book, as stated by the author, is a "drawing dictionary," to be used as a textbook by teachers, students and drafting-rooms as a basis for

uniformity in the making of mechanical drawings. The following features are covered in the dictionary: Lines; Letters and Lettering; Figures and Dimensions; Projections and Projected Views; Sectioning and Sectional Views; Methods of Dimensioning; Conventional Signs and Their Meanings; Finish Designations and Marks; Conventional Methods (the Draftsman's Idioms); Some Suggestions Regarding Designations and Abbreviations of Names; Lists on Drawings; A Few Examples of Drawings; and Suggestions Regarding the Compilation of Standard Data. No attempt has been made to cover shop systems, the purpose being to make the dictionary useful for conducting any method of drafting-room business. A proposed alphabet of lines is presented, and, in the presentation of this and other features of the book, the author states that he has endeavored to give the requirements and all necessary definitions, and, by argument, to show that what is proposed is reasonable.

**QUASI-PUBLIC CORPORATION ACCOUNTING AND MANAGEMENT.**

By John F. J. Mulhall. Morocco, 9½ x 6 in., 199 pp. Boston, Corporation Publishing Co., 1905. $5.00.

The principal and auxiliary books of a quasi-public corporation differ radically from those of the ordinary business corporation. It is stated that in this book the writer explains briefly the books, forms and methods necessary for the proper organization and management of such a business. The recording of all essential details of revenue, operation, maintenance and construction, with the least possible expenditure of time and labor consistent with good management, is also given, with explicit statements as to the recording of profits and loss, assets and liabilities. The Contents are: Organization; Securities; Water Works; Gas Works; Electric Light Works; Steam Heating Works; Telephone Companies; Electric Railways; Combined Inspection and Customer's Registers; Purchasing Department; Sales Department; Engineering Department; Chemical and Testing Department; Audits and Examinations; Depreciation; Funds and Dividends; Annuity, Compound Interest, and Sinking Fund Tables; Miscellaneous Account Forms; Miscellaneous Instrument Forms; Office Devices. There is an index of account forms and one of instrument forms.

Gifts have also been received from the following:

Am. Ry. Eng. and M. of W. Assoc. 1 vol.
Bates, L. W. 1 pam.
Bibliotheek der Technische Hoogeschool te Delft. 1 vol.
Brooklyn Public Library. 1 pam.
Buffalo, N. Y.-Dept. of Public Works. 1 vol.
Canada-Dept. of the Interior. 1 map.
Central R. R. Co. of New Jersey. 5 pam.
Chicago, Ill.-Mayor. 3 bound vol.
Cleveland, Ohio-Board of Public Service. 1 pam.
Cornell Univ. 1 vol.
*Engineering*. 10 vol.
Eng. Soc. of the School of Practical Sci., Univ. of Toronto. 1 vol.
Freeman, J. R., and C. R. Crane. 1 vol.
Great Britain-Patent Office. 8 vol., 3 pam.
Henriksen, Geschworner. 1 pam.
India-Secy. to the Govt. 2 pam.
Indiana-State Board of Health. 1 bound vol.
Los Angeles, Cal.-City Govt. 1 bound vol.
Louisville, Ky.-Commrs. of Sewerage. 1 pam.
McClintock, J. Y. 1 pam.
Madras-Public Works Dept. 1 pam.
Magruder, G. L. 1 pam.
Mexican Ry. Co., Limited. 4 pam.
Mich.-State Commr. of Railroads. 1 map.
Milwaukee, Wis.-Board of Public Works. 1 vol.
Mobile, Jackson & Kansas City R. R. Co. 1 pam.
New South Wales-Met. Board of Water Supply and Sewerage. 1 bound vol.
New York State-Comm. of Gas and Electricity. 1 bound vol.
Pennsylvania-State Dept. of Mines. 2 bound vol.
Philadelphia, Pa.-Bureau of Surveys. 1 bound vol.
Polytechnic Inst. of Brooklyn. 2 vol.
Poor's R. R. Manual Co. 1 bound vol.
Ry. Signal Assoc. 2 bound vol.
Rome, R. Univ. Romana-Scuola d'Applicaziono per gl'Ingegneri. 1 vol.
Smithsonian Institution. 1 pam., 1 vol.
Soc. of Engrs. 1 pam.
Switzerland-Eidgen. Hydrometrisches Bureau. 1 vol.
Thompson, R. A. 1 map.
Truck, Sigismund. 1 pam.
Union Pacific R. R. Co. 2 pam.
U. S. Bureau of Plant Industry. 1 pam.
U. S. Coast and Geodetic Survey. 1 pam.
U. S. Commr. of Patents. 1 vol.
U. S. Forest Service. 6 pam.
U. S. Isthmian Canal Comm. 3 pam.
U. S. Lake Survey Office. 1 map, 1 pam.
U. S. Office of Public Roads. 1 pam.
Univ. of Illinois-Eng. Exper. Station. 3 pam.
Western Australia-Geol. Survey. 7 pam.

## BY PURCHASE.

**Turbinen und Turbinenanlagen.** Von Viktor Gelpke. Berlin, Julius Springer, 1906.

**Theory and Calculation of Alternating Current Phenomena.** By Charles Proteus Steinmetz. Third Edition, Revised and Enlarged. New York, McGraw Publishing Company, 1900.

## SUMMARY OF ACCESSIONS.

From November 14th to December 5th, 1906.

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| Donations (including 7 duplicates) | 106 |
| By purchase | 2 |
| Total | 108 |

## MEMBERSHIP.

### ADDITIONS.

| MEMBERS. | Date of Membership. |
|---|---|
| BROWN, WILLIAM GERRIE. 740 Chamber of Commerce, Portland, Ore. | Nov. 7, 1906 |
| DOMENECH, MANUEL VICTOR. P. O. Box 220, Ponce, Porto Rico | July 9, 1906 |
| HARMAN, EUGENE LEONARD. U. S. Asst. Engr., Mississippi River Comm., 1115 Fullerton Bldg., St. Louis, Mo. | Oct. 3, 1906 |
| LION, LEON ELIE. Asst. Civ. Engr., Impvt., U. S. Military Academy at West Point, N.Y.; Address, Box 254, Newburgh, N.Y. | Jun. Feb. 1, 1898<br>Assoc. M. April 4, 1900<br>M. June 5, 1906 |
| SMITH, JOHN HERMAN. Div. Engr., K. C., M. & O. Ry., Clinton, Okla. | Nov. 7, 1906 |
| SYLVESTER, IRA WALLACE. Cons. Engr., Alexandria, La. | Nov. 7, 1906 |
| VAUGHN, CLARENCE GEORGE. Constr. Engr., Morgan's Louisiana & Texas R. R. & Steamship Co., 511 Natchez St., New Orleans, La. | Nov. 7, 1906 |
| WILLIAMSON, FRANK ROBERT. Asst. Engr., Scherzer Rolling Lift Bridge Co., 1616 Monadnock Blk., Chicago, Ill. | Nov. 7, 1906 |
| **ASSOCIATE MEMBERS.** | |
| BAUM, FRANK GEORGE. 3004 College Ave., Berkeley, Cal. | July 9, 1906 |
| CONNOR, SAMUEL POWERS. 220 West 107th St., New York City. | Nov. 7, 1906 |
| COWLES, WILLIAM PIERCE. 3227 Portland Ave., Minneapolis, Minn. | Nov. 7, 1906 |
| CUNNINGHAM, STANLEY, JR. 11 East 24th St., New York City. | Oct. 3, 1906 |
| DOYLE, JOHN STEPHEN. 2451 Maryland Ave., Baltimore, Md | Nov. 7, 1906 |
| DUDLEY, CHARLES TARBELL. 1160 Ellis St., San Francisco, Cal. | Jun. Sept. 6, 1904<br>Assoc. M. Oct. 3, 1906 |
| FIRTH, ELMER WALLACE. Asst. Engr., Topographical Bureau, Borough of Queens, New York City (Res., 1 John St., Jamaica, N. Y.). | Jun. Jan. 7, 1896<br>Assoc. M. Nov. 7, 1906 |
| HIGGINS, HERMAN KEENE. Asst. Engr., Isthmian Canal, Cristobal, Canal Zone, Panama | Nov. 7, 1906 |
| INGERSOLL, CHARLES ANTHONY. Asst. Engr., Dept. of New York State Engr., Barge Canal Office, Medina, N. Y. | Nov. 7, 1906 |
| KING, EVERETT EDGAR. 3941 Greer Ave., St. Louis, Mo. | Nov. 7, 1906 |
| MACKENZIE, GEORGE RIDDICK. 211 North 20th St., Philadelphia, Pa. | June 6, 1906 |

ASSOCIATE MEMBERS (*Continued*).

| | Date of Membership. |
|---|---|
| MÖNNICHE, TOLLEF BACHE. Glen Lyn, Va | Oct. 3, 1906 |
| NELSON, CLARENCE LOTARIO. Asst. Topographer, U. S. Geological Survey, Sacramento, Cal | Oct. 3, 1906 |
| ROBBINS, DANA WATKINS. Res. Engr., Dept. of State Engr., 190½ Partridge St., Albany, N. Y | Oct. 3, 1906 |
| SPEICHER, PIUS MELANTHON. Asst. Engr., Bureau of Filtration, 3209 Summer St., Philadelphia, Pa | Nov. 7, 1906 |
| SWATY, DAVID YOUNGS. Asst. Engr., North West System, Penn. Lines W. of Pitts., 1116 Union Station, Pittsburg, Pa. | Jun. Oct. 6, 1903<br>Assoc. M. Oct. 3, 1906 |
| VANCE, ALEXANDER MILTON. Pierce City, Mo | Nov. 7, 1906 |
| WHITE, ARTHUR BURR. City Engr., Corona, Cal | Nov. 7, 1906 |
| ZACHRY, JOHN LOW. P. O. Box 162, Davis, Ind. T | Nov. 7, 1906 |

ASSOCIATES.

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| HURST, GEORGE JOSEPH. 558 West 184th St., New York City | Nov. 7, 1906 |
| WATERBURY, LESLIE ABRAM. Instr. in Civ. Eng., Univ. of Illinois, 1109 California Ave., Urbana, Ill | Nov. 7, 1906 |

JUNIORS.

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|---|---|
| BULLEN, ROY. 326 Third St. East, Salt Lake City, Utah. | May 1, 1906 |
| CHANDLER, HORACE EDWARD. Dept. of Civ. Eng., Brown Univ., Providence, R. I | Sept. 4, 1906 |
| GRIFFIN, AUGUSTUS. Box 14, Modesto, Cal | Oct. 30, 1906 |
| MEHREN, EDWARD JOHN. 867 So. Central Park Ave., Chicago, Ill | Oct. 30, 1906 |
| PETERSON, GARFIELD CHRISTIAN. Care, C. L. Carpenter, Res. Engr., Gatun, Canal Zone, Panama | Oct. 2, 1906 |
| TRUFANT, ALTON PHILIP. With Durkee, White & Towne, Springfield, Mass | May 1, 1906 |
| VON BLÜCHER, CARL FELIX KILL-MAR. Ennis, Tex | Oct. 30, 1906 |
| WHITE, BYRON ELLSWORTH. 217 Genesee St., Utica, N. Y | Oct. 2, 1906 |

## DEATHS.

ABBOTT, ARTHUR VAUGHAN. Elected Junior, January 5th, 1881; Member, December 4th, 1901; died December 1st, 1906.

ASSERSON, PETER CHRISTIAN. Elected Member, July 5th, 1882; died December 6th, 1906.

CHENEY, JOHN EUGENE. Elected Member, May 7th, 1884; died September 25th, 1906.

HUMPHREYS, CHARLES. Elected Member, February 1st, 1905; died November 18th, 1906.

LAW, ARTHUR PRICE. Elected Associate Member, June 3d, 1903; died November 19th, 1906.

NICHOLSON, GEORGE BENSON. Elected Member, May 1st, 1878; died December 1st, 1906.

ROHNERT, BENNO. Elected Junior, April 3d, 1889; died September 1st, 1906.

SPENCER, SAMUEL. Elected Member, September 2d, 1885; died November 29th, 1906.

YOUNG, EDDY ELBERT. Elected Associate Member, January 6th, 1904; died June 1st, 1906.

## MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(November 12th to December 5th, 1906.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

### LIST OF PUBLICATIONS.

*In the subjoined list of articles, references are given by the number prefixed to each journal in this list.*

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month, 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeischrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.

## LIST OF ARTICLES.

### Bridge.

The Widnes and Runcorn Transporter-Bridge.* John James Webster, M. Inst. C. E. (63) Vol. 165.
A Problem Relating to Railway-Bridge Piers of Masonry or Brickwork.* Frederick Karl Esling. (63) Vol. 165.
Cantilever Bridge over the Seine at Passy; Metropolitan Railway of Paris.* R. Bonnin. (13) Nov. 15.
The Zambesi River Bridge.* (15) Nov. 16.
The Walnut Lane Bridge, Philadelphia.* (14) Nov. 17.
The New Orleans Railway Bridge.* Elmer L. Corthell. (14) Serial beginning Nov. 24.
The Anchor Arms of the Quebec Bridge; Notes on the General Design of the Arm Completed during the Summer.* (14) Dec. 1.

### Electrical.

The Design of Direct Current Motors.* Charles H. Bedell. (6) Nov.
Transformation of Electric Power into Light.* Charles Proteus Steinmetz. (42) Nov.
A New Primary Battery for Large Currents.* Carl Hering. (Abstract.) (3) Nov.
On the Measurement of the Constants of Telephone Lines.* Béla Gáti. (73) Nov. 2.
The High-Power Wireless Telegraph Station at Nauen near Berlin.* (73) Nov. 2.
Tests on Train Lighting Plant. (26) Nov. 2.
Two Electrical Factories at Birmingham.* (26) Nov. 9.
Single-Phase Currents from Three-Phase Supply.* Alfred Still. (73) Nov. 9.
Experiments with High Potentials.* E. Jona. (73) Nov. 9.
Recent Storage Battery Improvements.* Sherard Cowper-Coles. (73) Serial beginning Nov. 9.
Standard Conditions with Specifications for Telephones or other Low-Tension Wires Crossing Railway Tracks. E. E. Parsons. (Abstract of paper read before the Assoc. of Ry. Telegraph Supts.) (13) Nov. 15.
How Electricity Was Served to Consumers and Street Car Lines by the San Francisco Gas & Electric Co. After the Fire. L. E. Reynolds. (Paper read before the Pacific Coast Gas Assoc.) (83) Nov. 15; (24) Nov. 19.
Some Measurements on Phase Displacements in Resistances and Transformers.* Charles V. Drysdale. (73) Serial beginning Nov. 16.
A "Wireless" Station for Long-Distance Communication.* (26) Nov. 16.
A Method of Producing Undamped Electric Oscillations and Its Employment in Wireless Telegraphy.* Valdemar Poulsen. (Paper read before the Electrotechnical Soc.; abstract from the *Elektrotechnische Zeitschrift*.) (73) Nov. 16.

*Illustrated.

**Electrical—(Continued).**

Strains in Pole Lines.* Aug. J. Bowie, Jr. (27) Nov. 17.
The Determination of the Mean Horizontal Intensity of Incandescent Lamps by the Rotating Lamp Method.* Edward P. Hyde and F. E. Cady. (27) Nov. 17.
The Electrical Equipment of a Modern Cement Works.* (26) Nov. 23.
Siemens-Schuckert Alternating-Current Series Motors.* Rudolf Richter. (73) Nov. 23.
Some Points about Single Phase Motors. W. Langdon-Davies and F. B. O. Hawes. (Paper read before the Birmingham and District Electric Club.) (47) Nov. 24.
Station of the Wilkesbarre Gas & Electric Company at Wilkesbarre, Pa.* (27) Nov. 24.
Electrical Ignition in Internal Combustion Engines.* F. W. Springer. (27) Serial beginning Nov. 24.
Electric Cable Troubles. J. H. C. Brooking, A. M. I. E. E. (10) Dec.
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# AMERICAN SOCIETY OF CIVIL ENGINEERS.

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# PAPERS AND DISCUSSIONS.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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# PAPERS AND DISCUSSIONS.

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## THE FATIGUE OF CONCRETE.*

By J. L. Van Ornum, M. Am. Soc. C. E.

### General.

Since submitting the paper on "The Fatigue of Cement Products,"† which showed that, for neat-cement blocks in compression, repeated loading would definitely cause failure where the load was greater than about half the load necessary to crush the specimen with one application, the writer has been investigating the same phenomena where concrete was the material used. This research has included both concrete blocks in compression and reinforced concrete subjected to transverse loading; and, in developing this law of fatigue, about 600 tests have been made.

A large number of tests was absolutely necessary in order that the unavoidable variability in strength of individual test specimens, which occurs in such a material as concrete, even when the greatest care is taken in its fabrication, should be eliminated as much as possible by averaging a sufficient number of variable results, so that the average might represent, as closely as might be, the real value desired. It sometimes happens that, in testing concrete, values vary 20%, or even 30% or more, from the average value of the same concrete specimens. If, then, a specimen tested for the 100% load, causing it to fail with one application, happened to be 20% weaker

* This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

† *Transactions*, Am. Soc. C. E., Vol. LI, p. 443.

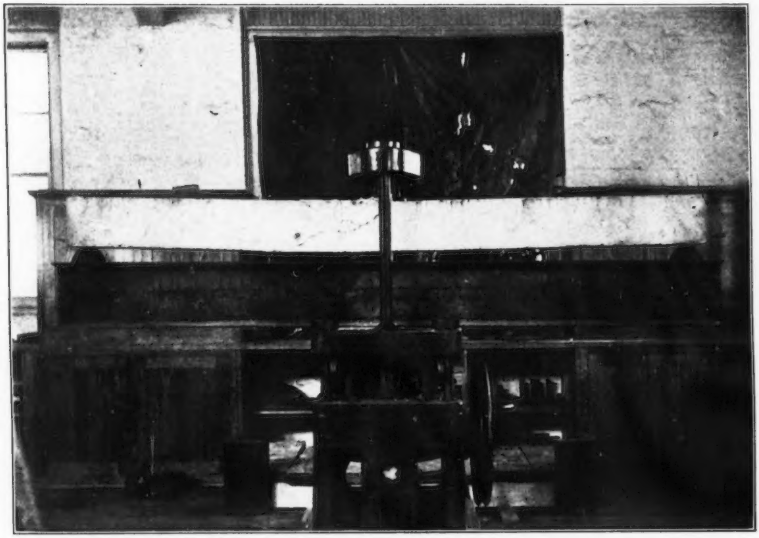


FIG. 1.—REINFORCED CONCRETE BEAM, AS SUBJECTED TO REPEATED LOADINGS.

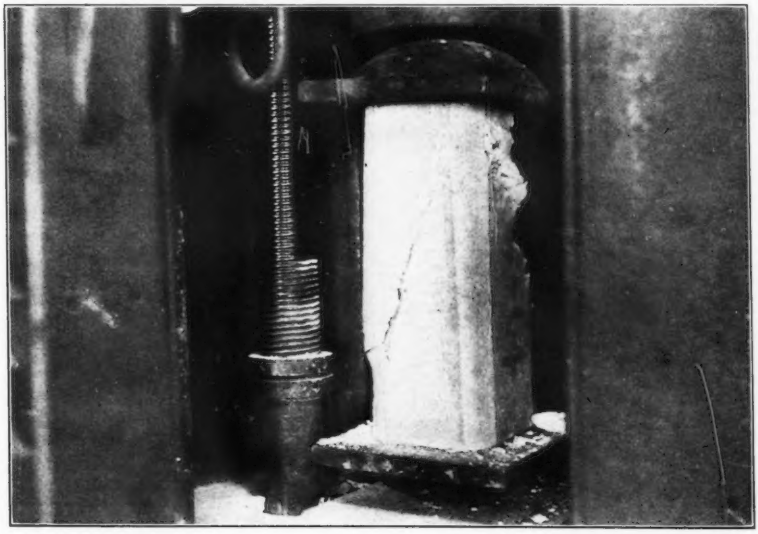


FIG. 2.—CONCRETE PRISM, AS SUBJECTED TO REPEATED LOADINGS.

than the average strength, and an average strength specimen to be tested by repeated loadings at a 75% load was actually loaded to 75% of the weaker load, the actually existing percentage of load in such test would have been 60% instead of the intended 75%, which latter value must be the recorded one. In other words, if the average compressive strength of a number of concrete specimens is actually 30 000 lb., and the trial specimen failed at 24 000 lb., the 75% loadings would erroneously be 18 000 lb.; and this specimen would actually take about 4 000 repetitions before failing, rather than about 500, as it evidently should. Of course, an opposite condition of test values would have a contrary effect; and there is evident a necessity of averaging a very considerable number of tests in order to minimize the effect of such influences.

In addition to the consideration just mentioned, precautions were taken to secure uniformity of material and treatment, as far as was practicable. While, even then, there were large variations in the strength of different specimens, such variability was probably decreased by always mixing in one batch enough material to make eight blocks or four beams, of which usually half would be tested for the 100% (or ultimate) strength and the remainder for fatigue.

All the concrete for all the tests was a 1:3:5 mixture, by volume. The cement was a standard American Portland cement, and was tested completely according to the specifications recommended by the Special Committee of the American Society of Civil Engineers on Uniform Tests of Cement*, and thus proved to be of general good quality. The sand was the Mississippi River sand, ordinarily used in the vicinity of St. Louis, Mo., for mortars and concretes. It is a water-worn sand, rather fine, and varying considerably in important characteristics with different consignments, as will be seen from the following facts: On a No. 10 sieve, from 5 to 10% was retained; passing a No. 10 sieve and retained on a No. 20 sieve, there was from 10 to 15%; No. 20 to No. 30, there was 15 to 27%; No. 30 to No. 40, 20 to 25%; and passing a No. 40 sieve, 23 to 50 per cent. The voids in the selected sizes of sand varied from about 38 to 30%; and for unscreened sand as delivered, from 33 to 26 per cent. The weight of the sand was about 99 to 110 lb. per cu. ft., when dry and moderately shaken.

* *Proceedings*, Am. Soc. C. E., January, 1903.

The stone for the concrete was the broken limestone in the vicinity of St. Louis, Mo., crushed to pass a 1½-in. screen. About one-half was larger than the 1-in. size, and about one-tenth was less than the ½-in. size. It weighed from 80 to 95 lb. per cu. ft., and its voids varied from 42 to 48 per cent. The percentage of voids in the 3 parts sand to 5 parts broken stone was from 16 to 19. While, from the theoretical point of view, it would probably have been more scientific to have screened all the sand and to have used selected proportions of the different sizes, thereby undoubtedly securing an increased uniformity of test results; still, for practical reasons, it was determined to use the unselected and unscreened materials, just as is done in engineering works of concrete, in the proportions 1:3:5, which would seem to satisfy fairly well any combination of the variable conditions of the materials mentioned above.

The weight of the resulting concrete when dry averaged 146½ lb. per cu. ft., the extreme variation being about 3 per cent. After fabrication, the concrete compression specimens were left in the moulds in air for 1 day, and the reinforced concrete beams for 2 days; when removed from the moulds, all specimens were placed in water for 2 weeks, and were then stored in air, protected from drafts, until tested.

As it was realized that the contemplated series of tests would require repetitions in number running into the hundreds of thousands (actually, the number of loadings reached a total of considerably more than half a million), it was deemed essential that an automatic apparatus be devised which would release the load on the specimen automatically when it reached the desired limit, and then at once allow the same load to be imposed again. This arrangement not only saved an immense amount of labor, but also permitted the tests to proceed uninterruptedly, night and day, until the specimen failed, the register, of course, tallying the number of repetitions so that this essential record should not be lost. The device was an electrical attachment to an ordinary Riehlé universal testing machine of the hydraulic type, an oil pump forcing oil into its cylinder to effect the loading. Whenever a specimen broke in the night, pumping would continue until the movable cross-head, which brings the pressure on the specimen, was lowered an inch or two be-

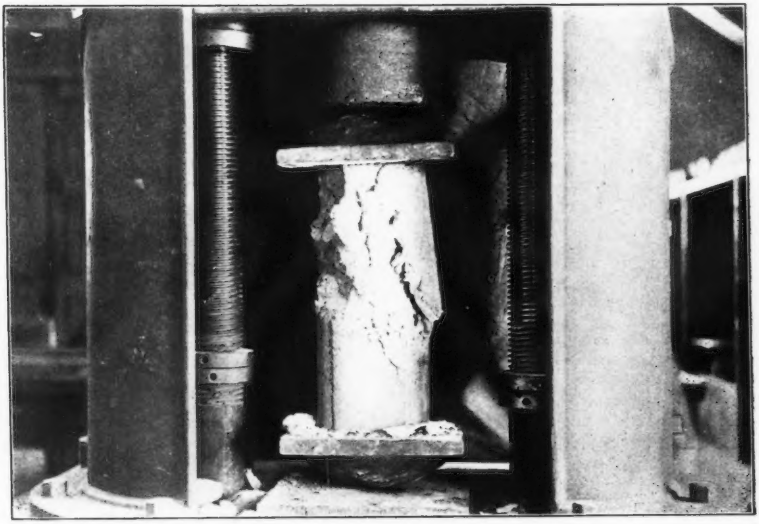


FIG. 1.—CONCRETE PRISM, JUST BEFORE COLLAPSE.

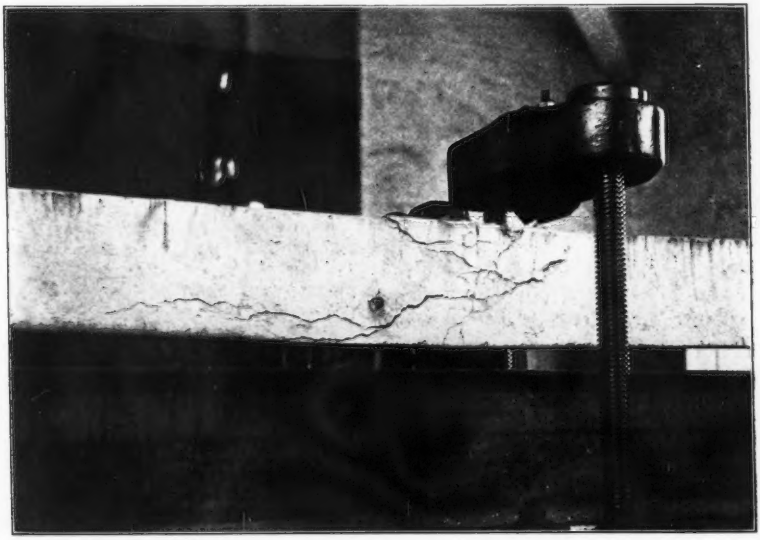


FIG. 2.—REINFORCED CONCRETE BEAM, JUST BEFORE COLLAPSE.

low its normal height; when this occurred it tripped a lever connecting with the handle of the starting compensator, thus shutting off the current from the motor driving the oil pump.

In the ordinary operation of the device, the flow of oil into and out of the cylinder of the testing machine, and therefore the repetition of loading, was effected by a piston (or plunger) valve which was actuated by the successive reversals of a rotating shaft threaded at the end to engage a female screw attached to the plunger. Rotation was communicated to the shaft by a pair of magnetic clutches built in the form of loose pulleys mounted on the shaft, and belt-driven in opposite directions, the clutches engaging successively with a disk keyed to the shaft, and situated between the two clutches. The necessary end play of the disk was permitted by fitting it to the shaft and key with a loose sliding fit.

The normal position of the plunger valve was such that the pump forced oil into the testing machine. When the load on the specimen reached the value set by the locked poise, the rising of the beam closed a circuit through one of the clutches, thereby attracting the disk and causing it to rotate in such a direction as to drain the oil from the testing machine by the opening of the plunger valve. The consequent dropping of the beam then opened the circuit, thus releasing the disk and stopping the travel of the valve.

The fall of pressure in the oil system then actuated an adjustable pressure valve which was arranged to close an electrical circuit through the other, or reversing, clutch, when the load on the specimen reached a predetermined minimum amount. The plunger valve was thereby closed, thus building up the load on the specimen. At the moment the plunger became fully seated, the circuit through the clutch was broken by the opening of a contact attached to the reciprocating nut of the plunger. The two magnetic clutches then revolved unmagnetized, ready for a repetition of the cycle, as already described. An automatic register was attached to this automatic device in such a way that it recorded the forward motion of the revolving shaft each time it released the pressure on the specimen.

### Compression Tests.

The concrete prisms on which these tests were made had the proportions already given, and series of tests were made at ages of 1

month and 1 year. These prisms were approximately 5 by 5 in. in section, and 12 in. high; the corners being rounded, the net section averaged (with very slight variation) 23.6 sq. in. Each end was capped in the making with about 1 in. of mortar in order to prevent a concentration of pressure where otherwise a piece of stone might extend to the surface. Still further to insure uniformity of loading throughout the cross-section, as soon as the prisms were removed from the water, the two ends were ground to plane surfaces in a specially constructed abrasion machine. When placed in the testing machine, after standing in air until the test was due, these plane surfaces were embedded in a thin layer of plaster of Paris (between sheets of dry oiled-paper) which was allowed to harden for at least 2 hours under a pressure of about 20 lb. per sq. in., and spherical bearings were used, both above and below the test specimen, to eliminate errors that would otherwise result from slight lack of parallelism of the two ground surfaces of contact. The writer considers the use of plaster of Paris of doubtful value where care is used in the grinding of bearing surfaces; but he does consider the use of spherical bearings essential in compression tests; although the labor of correctly centering the specimen is increased thereby.

The initial load, of perhaps 500 lb., represents the minimum loading of all specimens, the maximum repetition load being fixed by the position of the poise of the weighing beam. This minimum load was necessary to prevent the falling out of the specimen, which, of course, would have occurred if the load had been entirely removed, as the specimen stood on a spherical bearing. The rate at which repetitions of the maximum loading occurred depended upon the percentage which this load bore to the compressive strength of similar specimens as ordinarily obtained by simple crushing, being less for the higher percentages. This rate varied from 4 to 8 per minute. As a rule, when repetitions were begun upon a prism, the test was continuous night and day until failure occurred.

Generally, from each "mix" of concrete, two blocks were crushed in the ordinary way with one application of load, the average of the two recorded results being taken as the true "100%" load. If these two values were quite different, or if the following repetition tests, on the remaining specimens of the same "mix," were so erratic as

to indicate a probable erroneous value of this "100%" load, others were crushed, until an apparently average "100%" value was secured. Then a certain percentage of this "100%" value was taken as the repetition load for fatigue tests, and the testing was accomplished as indicated above.

Tables 1 and 2 give the results of the 1-month compression tests, the average crushing strength of the concrete at this age being 1 200 lb. per sq. in. Tables 3 and 4, similarly, exhibit the results of the 1-year tests, the average 100% strength being 1 580 lb. per sq. in., an increase of strength of about one-third more than the strength at the age of 1 month. While these repetition results can in no sense be considered as giving a precise average, because of the very great range in values as given (due to unavoidable causes already mentioned), still it is thought that the combined results do definitely indicate, and rather closely approximate, the true law of the fatigue of concrete.

In order to determine whether or not the rate of application of the repetitions has a noticeable effect upon the law of fatigue, tests have been made in which the rate of repetition was never less than 4 per hour, and averaged (due to interruptions of night hours, holidays and other periods of rest) one loading in about 5 hours.

TABLE 1.—ONE-MONTH COMPRESSION TESTS. 100% LOADS.

| | | | | |
|---|---|---|---|---|
| 30 000 | 32 610 | 23 500 | 31 650 | 37 280 |
| 20 000 | 30 100 | 30 500 | 32 230 | 26 780 |
| 31 140 | 31 280 | 30 120 | 33 200 | 21 020 |
| 25 820 | 23 000 | 26 000 | 26 400 | 26 500 |
| 25 650 | 25 000 | 24 000 | 27 610 | 19 800 |
| 25 130 | 23 020 | 36 560 | 35 480 | 22 850 |
| 27 270 | 23 100 | 26 000 | 30 840 | 24 780 |
| 27 400 | 20 970 | 25 800 | 31 220 | 34 150 |
| 28 450 | 26 240 | 31 200 | 29 950 | 27 660 |
| 27 640 | 23 200 | 25 800 | 24 200 | 30 810 |
| 30 900 | 22 540 | 26 700 | 28 190 | 30 200 |
| 19 280 | 26 000 | 28 040 | 35 160 | 26 800 |
| 31 090 | 37 500 | 25 720 | 31 880 | 26 800 |
| 27 230 | 22 740 | 28 100 | 37 000 | 30 020 |
| 23 250 | 23 210 | 30 200 | 25 400 | 37 060 |
| 34 400 | 30 780 | 32 500 | 27 800 | 23 090 |
| 33 800 | 30 100 | 29 750 | 26 600 | 23 480 |
| 23 330 | 27 400 | 28 000 | 36 000 | 30 870 |
| 32 930 | 35 600 | 29 700 | 21 500 | 25 400 |
| 36 860 | 26 200 | 31 570 | 24 000 | 23 430 |
| 30 040 | 28 000 | 34 160 | 19 800 | 29 340 |
| 35 240 | 24 800 | 26 720 | 32 150 | 32 040 |
| 31 360 | 33 000 | 28 410 | 25 700 | 30 500 |
| 25 380 | 32 900 | 35 760 | 25 220 | 25 620 |
| 26 800 | 32 110 | 33 810 | 32 290 | 29 050 |
| 24 640 | 24 600 | | | 22 940 |

Average of 128 = 28 350 lb.

TABLE 2.—REPETITION TESTS.

| 95% | 90% | 85% | 80% | 75% |
|---|---|---|---|---|
| 6 | 102 | 131 | 123 | 826 |
| 92 | 51 | 20 | 85 | 101 |
| 4 | 2 | 25 | 145 | 233 |
| 3 | 79 | 1 | 57 | 384 |
| 3 | 151 | 750 | 109 | 1 119 |
| 16 | 3 | 206 | 79 | 416 |
| 31 | 14 | 26 | 1 527 | 168 |
| 150 | 29 | 198 | 28 | |
| 13 | 91 | 91 | 128 | |
| 54 | 1 | | 656 | |
| 16 | 418 | | 3 | |
| 3 | 206 | | 37 | |
| 175 | 226 | | 124 | |
| 8 | 35 | | 22 | |
| 9 | 77 | | | |
| 3 | | | | |
| Av. of 16 = 37 | Av. of 15 = 99 | Av. of 9 = 161 | Av. of 14 = 223 | Av. of 7 = 464 |

| 70% | 65% | 60% | 55% | 50% |
|---|---|---|---|---|
| 135 | 2 227 | 2 016 | 443 | 10 711 |
| 332 | 185 | 666 | 5 025 | 21 070 |
| 4 405 | 246 | 596 | 1 113 | 19 800 |
| 280 | 207 | 1 431 | 165 | |
| 350 | 13 | 994 | 431 | |
| 324 | 32 | 356 | 15 629 | |
| 1 020 | 1 881 | 10 711 | 173 | |
| 1 345 | 4 005 | 9 210 | 2 064 | |
| 359 | 62 | 7 200 | 52 440 | |
| | 27 | | | |
| | 185 | | | |
| | 5 304 | | | |
| | 510 | | | |
| | 9 957 | | | |
| | 5 525 | | | |
| | 247 | | | |
| | 1 875 | | | |
| Av. of 9 = 950 | Av. of 17 = 1 911 | Av. of 9 = 3 687 | Av. of 9 = 8 609 | Av. of 3 = 17 194 |

TABLE 3.—ONE-YEAR COMPRESSION TESTS. 100% LOADS.

| | | | | |
|---|---|---|---|---|
| 34 260 | 33 400 | 33 750 | 36 680 | 44 900 |
| 46 670 | 26 440 | 29 150 | 44 840 | 38 650 |
| 48 400 | 45 200 | 44 100 | 48 160 | 49 600 |
| 36 200 | 26 800 | 30 200 | 36 540 | 35 570 |
| 39 200 | 39 860 | 35 330 | 36 000 | 32 720 |
| 43 040 | 31 840 | 38 700 | 35 690 | 32 830 |
| 32 000 | 35 150 | 35 660 | 42 500 | 37 740 |
| 30 200 | 37 500 | 33 900 | 44 950 | 42 700 |
| 34 400 | 37 600 | 34 600 | 27 100 | 39 000 |
| 43 350 | 34 150 | 27 350 | 37 000 | 32 000 |
| 33 800 | 38 600 | 37 850 | 40 490 | 45 960 |
| 39 240 | 41 400 | 31 000 | 37 700 | 44 400 |
| | | | | 35 600 |

Average of 61 = 37 370 lb.

TABLE 4.—REPETITION TESTS.

| 95% | 90% | 85% | 80% |
|---|---|---|---|
| 3 | 11 | 79 | 175 |
| 2 | 23 | 14 | 1 951 |
| 3 | 115 | 179 | 192 |
| 27 | 2 | 137 | 15 |
| 2 | 9 | 94 | 265 |
| 4 | 10 | 38 | 1 |
| 98 | 94 | 811 | 57 |
| 4 | 19 | 194 | 328 |
| 3 | 3 | 8 | 600 |
| 31 | 1 | 345 | 40 |
| | 12 | 139 | |
| | | 90 | |
| | | 3 | |
| | | 713 | |
| | | 47 | |
| Av. of 10 = 18 | Av. of 11 = 27 | Av. of 15 = 193 | Av. of 10 = 362 |

| 75% | 70% | 65% | 60% | 55% |
|---|---|---|---|---|
| 971 | 2 145 | 1 168 | 7 867 | 2 480 |
| 1 138 | 3 279 | 2 378 | 450 | 83 159 |
| 183 | 382 | 1 600 | 10 673 | 4 237 |
| 110 | 275 | 2 067 | 1 360 | 40 302 |
| 542 | 16 | 3 731 | 3 579 | |
| | 1 130 | | | |
| Av. of 5 = 589 | Av. of 6 = 1 230 | Av. of 5 = 2 189 | Av. of 5 = 4 786 | Av. of 4 = 32 545 |

In 50 tests made for this purpose (of which about three-fourths were compression specimens and the remainder were beams), in which the load percentage was intended to be between 85 and 92%, and averaged 89%, the average number of repetitions was, for the compression specimens averaging 90% load, 35 repetitions; and for the beams averaging 88% load, 62 repetitions. By comparing these results with those given in the tables preceding and following, and also with the general curve, there will be noticed no systematic difference in the relation between "percentage" and "number of repetitions," and certainly there is not evident any considerable increase in the number of repetitions necessary to cause failure even when the fastest rate of loading is reduced a hundred times, and where the average rate-ratio becomes as 1 to 1 500.

It is true that some other tests of effect of rate of loading* show a noticeable reduction of strength (or in number of repetitions

* As cited in Falk's recent work on "Cements, Mortars and Concretes," p. 67 *et seq.*

necessary to cause failure) with increased rate of application of load; but, in such cases, the frequency of repetitions has been much greater than any used in the tests by the writer; and he believes that where the rate of loading is greater than about 10 per minute there is produced upon the strength of concrete noticeable effect, which rapidly increases as the rate of repetition is increased; while, if the rate of loading is less than 8 or 10 per minute, there is probably little or no effect noticeable in varying such repetition rate.

### Reinforced Concrete Beams.

The reinforced concrete beams were 6 ft. long between supports, the extreme length being about 4 in. greater. In cross-section they were 4 in. wide and 6 in. high. The reinforcement consisted of two bars of plain steel, $\frac{1}{2}$ in. square, and placed with their centers 1 in. above the bottom of the beam and 1 in. inside the sides of the beam, respectively. The elastic limit of the steel was 29 000, and its maximum strength 59 000 lb. per sq. in. It will be noted that the percentage of steel was somewhat greater than 2; this large amount was used in order to make certain the failure of the concrete alone, essentially unaccompanied by any weakening effect that high unit stresses in the steel would occasion. The concrete was of the character already described. The treatment after fabrication, and until the test, was similar to that of the compression prisms.

For the tests, the reinforced concrete beams were supported on knife-edges and bearing plates rounded sufficiently to prevent crushing; the load was applied at the center of the supported length through a similar knife-edge and rounded bearing plate. The automatic apparatus already described controlled the repetitions of load, which varied from the determined maximum to a minimum of zero. The rate of application of the loads, of course, depended partly on the "percentage" (or test) load, varying from 2 to 4 per minute.

Tables 5 and 6 give details of the tests at the age of 1 month, and Tables 7 and 8 give similar tests at greater ages. It will be noticed that, in the latter tables, tests at 6 and 12 months are combined, partly because the results at these two ages contain no systematic differences, and partly because the number of tests at the age of 12 months are too few for independent use.

TABLE 5.—ONE-MONTH TESTS, REINFORCED CONCRETE BEAMS. 100% LOAD.

| | | | | |
|---|---|---|---|---|
| 2 800 | 2 950 | 2 050 | 2 440 | 2 400 |
| 2 860 | 3 250 | 2 930 | 2 610 | 3 460 |
| 3 760 | 3 940 | 2 470 | 2 460 | 2 920 |
| 2 860 | 2 680 | 2 360 | 2 920 | 2 600 |
| 3 530 | 3 050 | 2 080 | 2 200 | 3 820 |
| 3 760 | 3 650 | 3 490 | 3 060 | 2 720 |
| 3 500 | 3 150 | 2 980 | 2 630 | 2 060 |
| 2 400 | | | | |

Average of 36 = 2 909 lb.

TABLE 6.—REPETITION TESTS.

| 90–99% | | 80–89% | | 70–79% | | 60–69% | | 50–59% | |
|---|---|---|---|---|---|---|---|---|---|
| % | Repetitions. | % | Repetitions. | % | Repetitions. | % | Repetitions. | % | Repetitions. |
| 91 | 36 | 80 | 388 | 75 | 92 | 63 | 6 476 | 53 | 4 170 |
| 91 | 9 | 85 | 96 | 70 | 480 | 64 | 570 | 58 | 2 205 |
| 91 | 1 | 80 | 56 | 74 | 3 880 | 60 | 1 384 | 59 | 5 300 |
| 94 | 31 | 85 | 1 | 72 | 555 | 66 | 59 | 56 | 3 655 |
| 92 | 1 | 80 | 256 | 70 | 13 | 64 | 120 | 53 | 2 538 |
| | | 80 | 9 | 75 | 14 | 66 | 1 630 | 56 | 3 560 |
| | | 80 | 585 | 70 | 86 | 64 | 21 | 59 | 2 227 |
| | | 80 | 23 | 75 | 760 | 68 | 6 316 | 50 | 1 527 |
| | | 85 | ? | 70 | 79 | 68 | 165 | 59 | 5 400 |
| | | 85 | 75 | 70 | 155 | 60 | 162 | 59 | 7 670 |
| | | 80 | 227 | 77 | 516 | 65 | 2 507 | 53 | 14 080 |
| | | 86 | 334 | 77 | 1 600 | 62 | 34 | | |
| | | 86 | 74 | 77 | 39 | 69 | 2 016 | | |
| | | 80 | 1 | 70 | 24 | 67 | 1 622 | | |
| | | | | 74 | 1 310 | | | | |
| Av. of 5 = 92%; 16 repetitions. | | Av. of 14 = 83%; 152 repetitions. | | Av. of 15 = 73%; 640 repetitions. | | Av. of 14 = 65%; 1 649 repetitions. | | Av. of 11 = 56%; 4 757 repetitions. | |

From a study of the results of these fatigue tests at different ages, and both in compression and transverse loading, it is thought that the actual law of fatigue of concretes is fundamentally independent of such variations of conditions, the number of repetitions necessary to cause failure depending essentially upon the percentage which the test load bears to the full strength of the concrete. This proposition is borne out by the fact that such variation of values as exists in the summarized values of Tables 2, 4, 6 and 8 are far within the limits of accidental errors. The writer, therefore, has drawn the mean curve, Fig. 1, to represent graphically the summarized law of fatigue of concretes as variously set forth in the four numerical tables just mentioned.

TABLE 7.—SIX-MONTH AND TWELVE-MONTH TESTS, REINFORCED CONCRETE BEAMS. 100% LOADS.

| | | | |
|---|---|---|---|
| 5 100 | 3 890 | 3 400 | 5 130 |
| 3 300 | 3 540 | 4 750 | 4 640 |
| 3 020 | 4 230 | 5 140 | 4 940 |
| 4 080 | 3 440 | 5 000 | 5 210 |
| 3 860 | 3 610 | 4 350 | 5 170 |
| 4 660 | 4 060 | 4 970 | 3 180 |
| 3 090 | 3 600 | *4 100 | *4 700 |
| *4 120 | *4 850 | *4 100 | *4 000 |

Average of 32 = 4 226 lb.

* Results of tests at age of 12 months; all others made at age of 6 months.

TABLE 8.—REPETITION TESTS.

| 80–89% | | 70–79% | | 60–69% | | 50–59% | |
|---|---|---|---|---|---|---|---|
| % | Repetitions. | % | Repetitions. | % | Repetitions. | % | Repetitions. |
| 81 | 14 | 75 | 709 | 60 | 1 777 | 56 | 4 117 |
| 81 | * 18 | 72 | 492 | 67 | 2 970 | 55 | *4 190 |
| 80 | *140 | 70 | 1 643 | 65 | 2 735 | 59 | *4 915 |
| 80 | * 2 | 78 | 27 | 68 | 9 | | |
| 89 | * 9 | 75 | 312 | 68 | 2 608 | | |
| | | 79 | 113 | | | | |
| | | 70 | 317 | | | | |
| | | 74 | * 297 | | | | |
| | | 78 | *1 634 | | | | |
| | | 70 | * 507 | | | | |
| Av. of 5 = 82%; 37 repetitions. | | Av. of 10 = 74%; 605 repetitions. | | Av. of 5 = 66%; 1 948 repetitions. | | Av. of 3 = 57%; 4 407 repetitions. | |

* Results of tests at age of 12 months; all others made at age of 6 months.

It will be noted that the curve as drawn would become horizontal at about the 50% load, which would fix the limit at which fatigue can affect concrete at about half the strength of the concrete as usually determined. There is some uncertainty as to the exact value of this limiting percentage, but it is thought to be not great. The somewhat indefinite value of this limiting percentage results from the fact that the tediousness of tests at low percentages, and other adverse conditions, prevented making such tests great enough in number practically to eliminate accidental results.

It will be noted that the result of the three compression tests made at 50%, at the age of 1 month, show an average failure at somewhat more than 17 000 repetitions. The writer thinks this re-

sult to be accidental, for the reason just given, because the 55% average of the 1-year compression tests is nearly double that value, and also because the three tests in which the repetitions exceeded 40 000 did not fail normally, but were each arbitrarily crushed at the repetition recorded when they gave no indications of weakening after such a large number of repetitions. In detail, the "52 440" specimen given in the 55% column of Table 2 was crushed, after the recorded number of repetitions, under a load 55% in excess of its repetition loading; the "40 302" specimen recorded in the

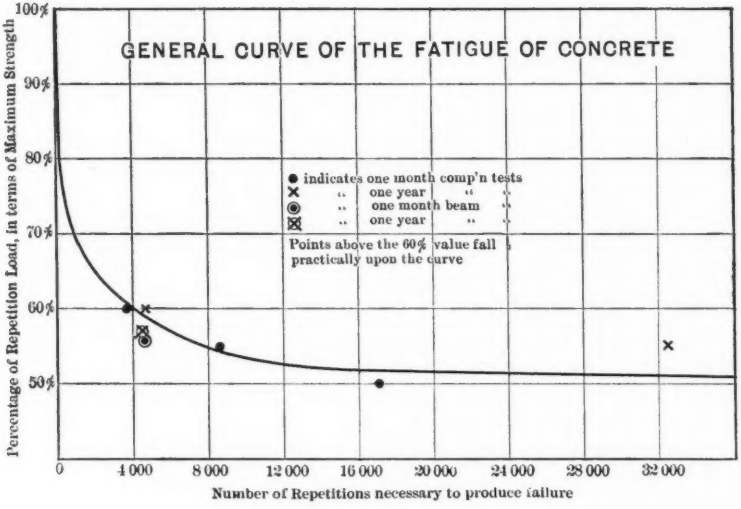



FIG. 1.

55% column of Table 4 was similarly crushed, to end the test, under a final load 81% above its repetition limit, or only ½% below its 100% load; while the "83 159" specimen, when arbitrarily crushed after bearing that number of repetitions, finally failed at a load of three times its repetition value, or a load 65% greater than the 100% value, as determined for this test. These three 55% specimens would probably have withstood an infinite number of repetitions.

These facts illustrate very clearly the inherent difficulty and, in fact, the real impossibility, of determining exactly the 100% load

value of any specimen treated by repeated loadings, and lead plainly to the inference that the 17 000-value of the 50%, 1-month compression tests is misleading. Therefore, the writer considers the true location of the curve to be above this low point, and in the vicinity where it is drawn.

The phenomena of failure of these beams involved first the development of tension cracks, then usually (but not always) diagonal cracks (often described as "shear cracks," "diagonal tension cracks," etc.), and last, a compression failure at the top of the beam near the point of application of the load—all these indications of weakness beginning with very minute manifestations, gradually and progressively increasing in size until failure occurred, and usually developing in the sequence just given.

The typical failure of the greater number of these beams is indicated in Fig. 2, which shows schematically the condition at the



FIG. 2.

moment of complete failure. The notched rectangle in solid black is at the center of the beam. The diagonal cracks usually began in the region below the half-height of the beam, extending in an oblique direction and developing gradually downward toward the nearer support, and becoming more horizontal with increase in length until, as a rule, they became horizontal in the plane of the upper side of the reinforcing bars; though sometimes they crossed the bars and united with tension cracks, and sometimes tension cracks extended across these bars, developing into real diagonal cracks of the form just mentioned, the latter in that case growing from below upward toward the load-point instead of in the contrary direction.

While a diagonal crack develops typically, as just described, during the middle period of the test, it also shows an increasing tendency to develop upward toward the load-point. When this failure is developed sufficiently to weaken the beam greatly and to restrict the compressive area, failure by compression begins, and progresses relatively rapidly to a complete collapse. Occasionally, instead of compressive failure manifesting itself so definitely and

vitally, the whole prism of concrete (shown in Fig. 3, on the right of the load-point, the figure being drawn just before final failure) above the curved diagonal crack, which finally extended just above



FIG. 3.

the reinforcing bars to the very end of the beam, broke completely away from the remainder of the beam; thus destroying its load-carrying capacity.

Sometimes, the beams, somewhat weakened by the tension cracks first developing, finally failed without the intervening development of diagonal cracks of a serious nature, as indicated in Fig. 4, drawn somewhat before collapse occurred.



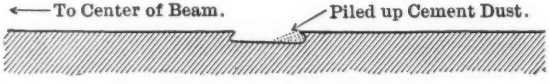
FIG. 4.

In the large majority of cases, those in which the development of diagonal cracks formed an essential factor in the fatigue of the beam, it appears that the gradual and progressive destruction of the adhesive bond of the concrete to the steel produced a vital influence upon the phenomena. Of course, usually, but not invariably, this destruction of the adhesion originated near the center (of length) of the beam, and progressed toward, without reaching, the ends. This slipping of the bars in the concrete was shown to be closely related to the development of the diagonal cracks, by breaking open beams, previous to final failure, both before and after the appearance of these diagonal cracks, the evidences of slipping being present after diagonal cracks developed, but usually not evident before.

These evidences of slipping were various. On breaking apart the beams, there was found at the ends a noticeable and effective tendency of the concrete to adhere to the steel; while in the middle portion there was a space over which this adhesion was entirely lacking. The evidence alone is not convincing, but when considered in connection with the phenomena following, it would seem

to be conclusive. Close examination disclosed the fact that, where the bond remained effective, the surface remained dull; but it had a polished, glassy appearance when the bond seemed broken. Often such surfaces revealed minute, but plainly discernible, horizontal striations. These must have been caused by a relative longitudinal movement taking place between the surfaces of the two materials, thus etching the smooth concrete surfaces by small projections from the steel. Such striations were rarely found when essentially a compressive failure occurred, but they were invariably present when diagonal cracks were prominently in evidence. Certainly, this relative longitudinal movement could not occur while the adhesive bond was effective.

Again, occasional, very shallow, cavities (perhaps $\frac{1}{4}$ in. long, half as wide and $\frac{1}{100}$ in. deep) in the reinforcing bars were found, in one end of which there was a most finely pulverized cement dust, where the above-mentioned evidences of slipping were also present. This cement dust was invariably at the side of the depression toward the nearest place of unbroken adhesion, the remainder of the cavity being empty, as indicated in the normal section, Fig. 5. Evidently, this phenomenon must indicate a rela-




SECTION OF REINFORCING BAR.

FIG. 5.

tive longitudinal movement of the two materials, necessarily taking place only after the bond was destroyed, the sharp edge of the depression scraping off particles from the concrete and receiving them as repetitions continued.

Another phenomenon, which the writer can explain only by the same proposition, was the occurrence sometimes of a succession of distinct, metallic reports, plainly heard when the load was being applied, followed by a continuous low, rasping sound as the beam was relieved of its load. This certainly proceeded from the interior of the beam, as made evident by careful auditory scrutiny and by the fact that no external deterioration of the beam was discoverable at the same time. It is believed that it was caused by the sudden

breaking in detail of the adhesive bond at points where its unusual strength brought a concentration of stresses upon them.

The adhesive strength of concrete to steel, low in value at best, is undoubtedly severely tried by repeated application and relief of load, and the consequent successive production and relief of the various internal stresses which tax so severely this essential and vital factor of reinforced concrete design and construction. Passing without comment the acknowledged fact that scale or thick rust will seriously impair the adhesion, it may be said that numerous critical examinations plainly indicated that any rust on the metal (while completely absorbed by the concrete and so effectively preventing further corrosion) did materially lessen the normal adhesive power of the concrete; the bond was often found lacking opposite the rust discolorations on the concrete, while remaining firm on each side where rust had been entirely absent; and, where the adhesive bond was destroyed in the middle portion of the beam, this destruction habitually terminated in a discolored section, apparently indicating the encountering of an increased adhesive resistance at the cleaner portions of the steel.

Another fact that has escaped deserved attention is the probability that a material excess of water used in mixing the concrete apparently lessens its adhesive power. It is realized that a moderately wet mixture is desirable, in order to prevent voids in the concrete as ordinarily placed, and especially to secure sufficient plasticity to insure a complete filling of the space round and below the network of reinforcing steel; but there seems to be a real danger that the reaction against dry concrete is being carried too far. An excessively wet concrete, not only contains numerous globules of water which, when absorbed, leave the concrete porous, but these, also, especially weaken the adhesion of the concrete to the steel, because there is a tendency for such water globules to seek the surface of the reinforcement, particularly on the under side. The weakening of the bond from this cause was evident in certain beams in which the adhesion was noticeably weak, the water cavities being apparent at the bottom and sides of the steel bars.

### Elastic Behavior.

In order, if possible, to learn more of the contributing and complementary phenomena in the fatigue of concrete, observations were

frequently taken to disclose any changes that might occur in the elastic properties of the test specimens. About 100 such beams and prisms were thus observed, the number of observation readings involved in this investigation reaching perhaps 10 000.

In this experimental research upon the compression prisms, dial compressometers were clamped upon the specimens by steel collars placed 8 in. apart. The dials read to ten-thousandths of an inch. Readings were taken during the first application of the load, during the first repetition of the load, and at intervals during the life of the specimen under the repetition treatment. These observed strains, with the corresponding stresses as recorded, were reduced to unit strains and stresses, and plotted as in the lower part of Figs. 6 and 7. In determining the value of the modulus of elasticity at different stages of the fatigue-history of the prism, it seemed that the only practicable valuation for comparative purposes was to divide the total unit stress (at the repetition limit) by the total unit strain (occurring between the zero load and the repetition limit) regardless of any intermediate variations in the slope of the stress-strain curve. As thus computed, the variation in value of the modulus of elasticity was determined for various compression specimens and plotted, as illustrated in the upper parts of Figs. 6 and 7. These are mean values; the extreme range of all the tests was about 30 per cent.

The graphs of Fig. 6 are typical of the observations on compression specimens where the repetition load was great enough to cause final failure by fatigue. Nearly all the compressive elastic observations were of this character. The particular prism represented in this diagram failed on 332 repetitions, and six readings were taken on it, as indicated. It will be noticed that the plot for "first loading" is practically straight in its lower part, but convex (to the left) in its upper portion; while the second loading (first repetition) has removed this convexity, giving a practically straight line about parallel to the straight part of the first line. This reduction of a variable modulus of elasticity to a constant modulus throughout the load-range is characteristic of the first elastic stage. The second stage is characterized by a gradual increase in the slope of the plotted line, or, in other words, a reduction in the value of the (constant) modulus of elasticity, the plotted curve, however, still

remaining straight for its whole length. This second stage bears a very close relation to the number of repetitions necessary to destroy the specimen. In prisms tested at a high percentage, where the number of repetitions to cause failure are few, this stage does not long continue; but when the test is at a low percentage, requiring a relatively great number of repetitions to rupture the specimen finally, the far greater part of this increase in repetitions is spent in passing through this second stage. The third stage begins rela-

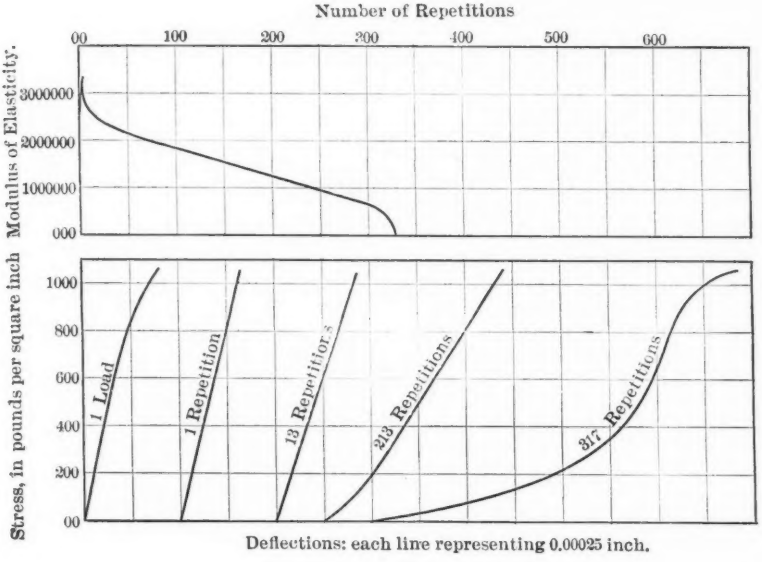



FIG. 6.

tively near to the failure of the specimen, and seem to indicate the beginning of the breaking down of its structure; it is characterized by a concavity developing in the lower part of the diagram. The last stage develops an additional curvature in the upper part of the plot, this being convex. The concave and convex curves rapidly increase in length, and then join, thus forming a reverse curve, which, at the same time, continually increases in its horizontal reach until complete failure occurs. These characteristics are plainly indicated in the five curves in the lower part of Fig. 6,

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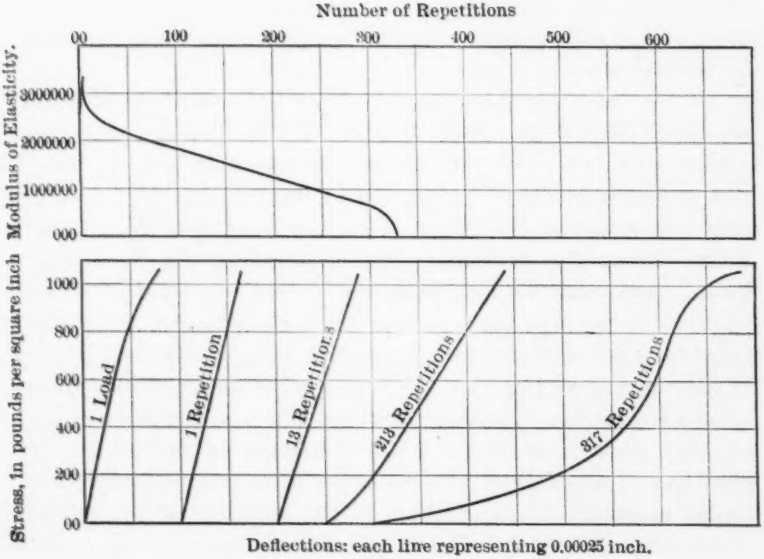



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the second stage being represented by two straight lines with somewhat different slopes, while each of the other stages is represented by one curve for each.

In the upper part of Fig. 6 is graphically represented the change in the modulus of elasticity. Characteristic facts are the sudden increase in its value at the first repetition, its rapid reduction to about its original value in the first few repetitions, its straight, sloping portion (which occupies a relatively greater part of the whole length of such curve when the number of repetitions to produce failure are greater), and the final increasingly rapid downward curve of the graph as the end is approached, finally reducing in value to practically zero.

At the beginning there seems to be an attempt of the concrete to adjust itself to the load conditions. Then quickly comes the critical stage, where, as in such cases as now described, the material is unable to endure the burden successfully, as is made evident by the regular diminution of the (constant) modulus of elasticity; though this diminution takes place slowly for the smaller loads. Then, near the end, comes the increasingly rapid reduction in its value, the modulus here becoming very noticeably of variable value from the beginning to the maximum value of any one loading. It was the writer's intention to attempt to determine whether these phenomena of elastic behavior were due to a breaking-down of the adhesive strength or of the cohesive strength of the cement, or possibly to a combination of these causes or to other causes, by extended microscopical examination of the structure of the prisms at critical periods of their behavior; but unavoidable adverse conditions prevented.

A few compression prisms were similarly observed where the imposed repetition load was too low to cause final failure, and these showed a radically different elastic behavior. In general, the first two stages mentioned above were again manifest, while the third and fourth were wanting. Fig. 7 shows these facts graphically for a specimen that withstood more than 30 000 repetitions, and was then crushed at a load as great as that of the average of the other three twin-specimens broken without repetition, the graphs being drawn similarly in every way to those of Fig. 6. The fact is noticeable that all the stress-strain graphs (except perhaps the first) are

straight lines; and that the modulus curve, which, as before, suddenly increases and then rapidly decreases in value, quickly approaches horizontally in direction, with its asymptote having about two-thirds its maximum value, which implies that an infinite number of repetitions would not reduce the modulus of elasticity below this two-thirds value. It would probably be a valuable investigation to impose a large number of repeated loadings varying in intensity from one-eighth to one-third of the 100% load (instead of about

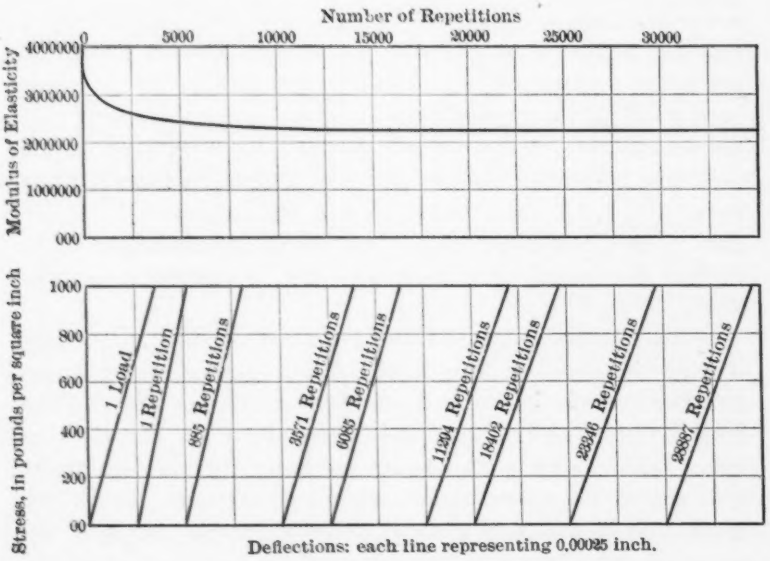



FIG. 7.

one-half load as in this case), to determine whether this two-thirds value of the modulus is general; it is likely that the fraction would be somewhat larger as the percentage of the repeated load becomes less.

In addition to the above-mentioned phenomena, there always occurred a permanent set in all the specimens as a result of the first few repetitions. In the case of the few observations represented by Fig. 7, typifying infinite endurance, evidences of permanent set rapidly disappeared. In the case of the greater number of tests,

representing prisms which finally failed under repeated loadings as typified by Fig. 6, the permanent set became comparatively small during the second stage, but again became more rapid in the third and fourth stages, and increasingly so toward the end.

All these phenomena will assume added definiteness if interpreted according to the theory of resilience. In the case of the specimens subjected to repetitions less in intensity than that load representing what may be called the elastic limit of the concrete (the actual or veritable elastic limit as typified in Fig. 7, not the artificially high one illustrated in Fig. 6, which is sustained for a time but cannot be maintained), the material speedily adjusts itself to the condition which enables it to give back all the work done upon it. When the repeated loadings of the prisms are greater than the elastic limit of the concrete, some of the work done on the specimens is absorbed, resulting in elastic changes that progressively accumulate and necessarily culminate in the collapse of the specimen. This consideration had its due weight in deciding the writer to draw the general curve of fatigue (Fig. 1) tangent to the 50% line.

A considerable number of the reinforced concrete beams were similarly observed, readings being taken to determine the aggregate "load off" and "load on" deflections at different stages of the fatigue test. The results of these observations are illustrated in Fig. 8, which is the plotted representation of the complete results with one of the beams, and is fairly representative, though not typical. Ordinates to the "total deflection" curve represent the maximum deflections when the full repetition load is on, measured downward from the original level of the center of the beam before the first loading was applied; likewise, ordinates to the "permanent set" curve represent deflections, similarly measured, when the beam is relieved of the repetition load. The vertically shaded portion of the diagram represents, then, the vertical range of deflections from the first to the last repetition of the load.

The curves indicate five different elastic conditions of the reinforced beam. The first is where the curves slope downward at the beginning, as the beam is adjusting itself to load conditions, and small tension cracks form. The second is characterized by only a slight downward slope of the lines, indicating a considerable

range in which internal conditions are but slightly changing. The third is shown by a rapid downward slope of the curves caused by the progressive breaking of the bond between the concrete and its reinforcement, with the accompanying manifestations of rapidly enlarging tension cracks or diagonal cracks, or both. The fourth is characterized by another nearly horizontal segment of the curves resulting from a second state of nearly perfect elastic equilibrium. The fifth condition is shown by another violent downward slope to the curves, structurally manifesting itself in the progressive breaking down of the concrete in compression, and ending in the complete collapse of the beam.

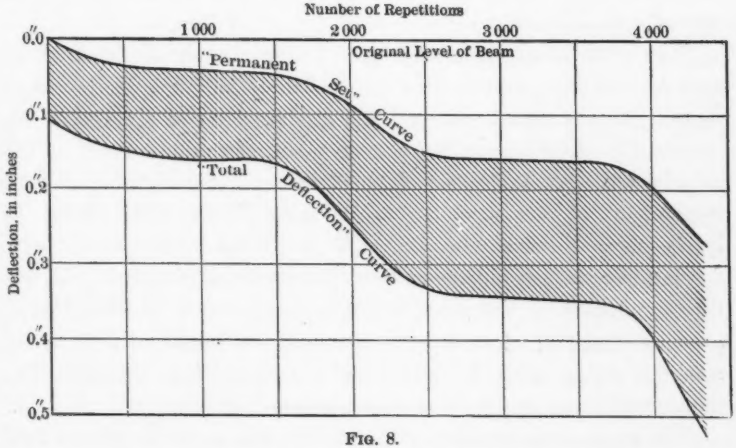



FIG. 8.

These curves should be considered broadly characteristic, but by no means minutely typical. Often, one or more of the five characteristic sections just described is blended with others, as the corresponding structural changes they indicate may be taking place simultaneously. Sometimes these changes overlap so that the resulting curves are much more regular. Occasionally, another change of direction is added, as a new factor of weakness or resistance may manifest itself; and sometimes one of these characteristic conditions of curve-slope may disappear entirely because of the entire absence of its cause. For a beam loaded with less than a 50% load, the first two segments only of the curves exist, the first horizontal portion rapidly becoming truly horizontal and the vertical

intercept between the curves not increasing in length as repetitions continue.

### Fatigue of Bond of Concrete to Steel.

For these tests, $\frac{5}{8}$-in. square, plain steel bars were embedded in concrete of the previously-mentioned proportions, the bar being placed with its center 1 in. from the tension face of the embedding prism and midway between the sides. These embedding prisms were 4 by 4 in. in cross-section and 15 in. long. These specimens were made with great care, and were very thoroughly tamped. They remained in the moulds for 2 days, were then placed in water for 7 days, and then stored in air for 3 weeks, thus being tested at an age of 1 month.

The machine devised to act upon the specimens consisted of two parallel steel struts, traveling in guides, to which a reciprocating movement was given. Beyond the guides, a metal cross-head was attached to these struts, faced with $1\frac{1}{2}$ in. of oak. In front of this oak face the specimen was clamped into a quite rigid frame, the attachment of the specimen to its independent frame being by heavy screw-clutches clamping the projecting ends of the reinforcing bar just beyond the ends of the concrete. The specimen was thus supported by the metal reinforcement, and a combined blow, pressure, and the accompanying vibration was imparted to it by the machine acting upon the surface of the embedding concrete. The number of blows delivered per minute was 150.

The specimens were set in their adjustable supports so as to encroach upon the extreme reach of the striking head $\frac{7}{100}$ in. Measurement developed the fact that each blow imparted to the specimen about 740 in-lb. of work; of this amount, somewhat less than one-tenth was found to be expended in initial impact, an unknown amount was lost through the beam supports, and the remainder was imparted to the specimen in producing bending stresses, vibration, etc. The effect on the test specimens produced by this treatment, therefore, is seen to be very severe, especially producing those effects which are often thought to prove destructive to the bond between the concrete and the steel; no one watching and hearing the action of the machine upon the test piece could doubt this severity of treatment.

In eighteen specimens the rods were pulled from the concrete without subjection to such preliminary fatigue treatment. For this

case the average value of the strength of the bond was 150 lb. per sq. in. of surface of contact, the extreme range from this mean value being about 35%; after the initial rupture of the bond, the weighing beam was again balanced as the bar continued to slip from the surrounding concrete, giving a frictional or sliding resistance averaging 100 lb. per sq. in. of surface.

Of the thirty specimens subjected to the fatigue treatment of the machine, the number of blows given to each averaging 50 000, the average initial unit value of the bond was found to be 125 lb. per sq. in. of surface, and the later frictional resistance, 90 lb. per sq. in.; the range in values was about as before.

The rigorous treatment described reduced, then, the value of the bond somewhat less than 20% in average value, and in no case as much as 50% per cent. However, it is not supposed that this reduction in value would in no case be more than the percentage given, for it might easily be greater or less. It will be noted that the total value of the bond consists of two parts, the adhesion proper and the frictional resistance or "grip" of the concrete to the steel, independent of its adhesion. This frictional resistance is much the larger of the two, the value of the adhesion, proper, apparently being about 50 lb. per sq. in. The "grip" of the concrete upon the steel is particularly dependent upon any effect of change of volume of the enveloping concrete, during both its setting and its hardening; and, consequently, its hygroscopic condition must constitute an important factor. The writer believes that very variable values would result from variations in the treatment of reinforced concrete, especially in connection with the presence or absence of water after it sets.

The same considerations may explain the low value found for the bond in the uninjured specimens, as compared with the greater strength reported by many experimenters, but agreeing more nearly with the lower values indicated by Considère, Hartmann and others. Variations due to proportions of ingredients, age, conditions of materials, and other considerations have received much attention; probably many discrepancies still remaining in values obtained by different experimenters would be explained if the moisture conditions of the specimens, from fabrication to test, were carefully scrutinized in their effect upon change of volume of the concrete as affecting the intensity of bond.

### Correlated Considerations.

Inasmuch as neat cement prisms and concrete are definitely affected by fatigue, the inference naturally follows that stone, brick and other engineering materials of the same comminuible character must also be similarly affected. Such scattering tests as other experimenters have published all corroborate this proposition, but results, so far, are too meager to indicate whether or not they present essentially the same law in detail as that herein stated for concrete.

Another natural inference would be, that, as concrete is subject to fatigue through the agency of repeated loadings, it would be affected similarly by a constant, static load of corresponding intensity. Tests of this kind are rare. The writer compressed two concrete prisms with a static load of 90% of their crushing strength, and each of the two specimens withstood this test successfully for a month, with no appearance of failure in that length of time. A slate beam, similarly, resisted a 90% load for about 2 months. A few concrete blocks failed in compression in a few hours under constant pressure of higher percentage. Three such cases are recorded* where stone was the material tested. Because the research work in this particular line is extremely difficult, on account of the time element involved, the writer has thought that the situation might best be indicated by comparing elastic behavior. A reinforced concrete beam thus tested under a 90% load has not failed in 8 months; but its "total deflection" curve is similar to the first portion of a similar curve (perhaps the first quarter of it) of a 90% beam tested by repetitions, as illustrated in Fig. 8. At the present time, only the most general conclusions (and these subject to possible later modification) can be drawn with reference to this subject, which is of some scientific and practical interest. Undoubtedly, such materials are subject to fatigue under a constant load of high intensity. Probably such effect does not exist below a considerable load, such as a 50% load. Apparently, its effects are produced very slowly, as it takes days and perhaps weeks or months to produce an effect corresponding to that of each repetition where the loading is intermittent. An unexpected phenomenon is that

* In Buckley's "Quarrying Industry of Missouri," 1904, p. 299.

(at a certain fixed, constant deflection) the poised weighing beam occasionally rises, instead of (as usual) gradually falling.

Of course, certain facts mentioned in this paper, such as the sequence of the cracks in the reinforced concrete beams, result from the particular details of their construction, and therefore are not general. The writer trusts that reporting such occasional results of limited applicability will in no way obscure the essentially general import of the main phenomena presented. Among the facts developed in these experiments the writer would invite particular attention to the following:

The fatigue of concrete under loads of high percentage is a definite fact; its influence is limited to an intensity of about 50% of the compressive strength of the material, as usually determined. Combining this fact with an allowance of 30% for range in values of compressive strength of concrete of supposed uniform composition and treatment, it is seen that designers of concrete or reinforced concrete must necessarily use a factor of safety of more than three. This consideration does not affect the practice of conservative design; but it does convey a definite warning against the use of working stresses which are too high.

With reinforcing bars having no mechanical bond, the reduced value of the bond caused by great excess of water in mixing the concrete, by rust, scale, etc., is considerable, and, especially, the effect of moisture condition, in expanding or contracting the concrete and so affecting the strength of bond, seems to be a consideration worthy of attention and of more precise and extended investigation.

While the elastic behavior of concrete within the fatigue limit is interesting and valuable in aiding in the more complete understanding of the phenomena of fatigue, the elastic properties of concrete repeatedly stressed to lower percentages is particularly pertinent. The writer's results agree with other experimental results in finding that concrete thus stressed has imparted to it a definite elastic limit, within which stresses are proportional to strains; his results extend this fact in indicating that repetitions indefinitely repeated, if below the fatigue limit, do not alter those propositions. A logical deduction from these facts would seem to be that all formulas for reinforced concrete design, which are intended to give

stress values under service conditions, should be based on this hypothesis of direct proportionality of stresses to strains, leaving strictly all parabolic or other curved stress-strain ratios for their legitimate application to conditions existing on the first application of load or at failure.

The tests and results would seem to add a third value for the modulus of elasticity of concrete. Many experimenters have used a value derived from conditions existing at the first application of the load. Others have made use of a value similarly secured after a permanent set had been given the concrete by a previous loading, and sometimes corresponding to the "first repetition" curve of Fig. 7, and giving a numerical value, perhaps 20 or 30% greater than that first mentioned. While it would seem to the writer that, although special circumstances would sometimes require the use of one or the other of the values just mentioned, ordinarily, engineers should use in all formulas and studies for working conditions, where a modulus of elasticity is used, the value to which it is reduced by a great number of repetitions; that is, the asymptotic value as typically indicated in the upper part of Fig. 7, which value may be found to be perhaps 80% of the initial values as frequently derived, or about 60% of the maximum value.

The experiments herein described were made in the Civil Engineering Laboratory of Washington University, during the past three years, and largely as thesis work. Acknowledgment is gladly made of the co-operation of Messrs. Hans Schantl, W. W. Horner, M. Schuyler, C. K. Traber, C. H. L. Cassell, J. M. Bischoff, and S. F. Jones, all former students, to whose interest and work much credit is due.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

# PAPERS AND DISCUSSIONS.

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## ADDITIONAL INFORMATION ON THE DURABILITY OF WOODEN STAVE PIPE.

### Discussion.*

By G. P. Hawley, Assoc. M. Am. Soc. C. E.

Mr. Hawley.

G. P. Hawley, Assoc. M. Am. Soc. C. E. (by letter).—In 1905 the water-works system of DePere, Wis., was enlarged and improved under the writer's supervision. Some mains were replaced by larger ones, and in many other places the pipes were uncovered to make connections and repairs, so that there was abundant opportunity for examining the old pipe, laid during the period from 1886 to 1888. The old system was under the natural pressure of Artesian wells. This was said to be about 40 lb. per sq. in. when installed, but the pressure has gradually fallen to less than 20 lb. at the present time, and therefore pumping has been resorted to.

The old mains consisted of pine logs, turned and bored from one piece, in various lengths up to about 13 ft. They were wrapped with continuous iron bands and covered with a tar mixture to protect the bands from rust. They were then rolled in saw-dust to prevent sticking. The three sizes used had internal diameters of 2, 4 and 6 in., and external diameters of 4, 7¼ and 10 in., respectively.

From observations made in many different sections of the system, the wood was found to be in a perfect state of preservation in every case. Where there has been any trouble, it has been due to the bands rusting and allowing the pipe to split under the pres-

* This discussion (of the paper by Arthur L. Adams, M. Am. Soc. C. E., printed in *Proceedings* for September, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Hawley.

sure, and can be traced to local causes. Usually, the coating had been knocked off, in making connections, digging sewer trenches, etc., thus exposing the bands to rust; otherwise, on removing the tar coating, the iron was found as bright as new.

The pipes lie about 4 ft. deep, mostly in a heavy red clay. One stretch of about 1 000 ft. through sand and sandy clay was replaced by larger pipe; here the pipe coating had many blisters, under some of them water had penetrated, and the bands had commenced to rust; this was particularly noticeable in the 2-in. size; the 4 and 6-in. pipes, having a heavier coating, were very little affected.

Since completing the new system, a pressure of from 60 to 70 lb. per sq. in. has been maintained on these old pipes (more than a year), and, except for some local defect, as above noted, they have given no trouble.

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# PAPERS AND DISCUSSIONS.

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## STEAM LOCOMOTIVE AND ELECTRIC OPERATION FOR TRUNK-LINE TRAFFIC— A COMPARISON OF COSTS AND EARNINGS.

### Discussion.*

By F. J. Sprague, M. Am. Soc. C. E.

Mr. Sprague.

Frank J. Sprague, M. Am. Soc. C. E.—The speaker finds it difficult to discuss this paper as fully as he would like. He will not take up the mechanical theory of construction, so ably worked out, because, as a whole, the paper is a plea for the electric operation of a trunk-line railway by a specific method, on the score of economy, and is based upon the assumption that the various claims made during the past six years for single-phase operation have been justified by accomplished results, which, up to the present, is not a fact.

The arguments advanced seem to be somewhat vitiated by a number of statements concerning both direct-current and single-phase operation which will not bear critical analysis. The speaker, therefore, will make only some random comments.

First of all, he quite agrees with Mr. Mayer in his general conclusion as to the necessity of higher potentials, but is quite at variance with that conclusion if the contention be that these can be effective only through the agency of single-phase alternating currents.

* This discussion (of the paper by Joseph Mayer, M. Am. Soc. C. E., printed in *Proceedings* for September, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members.

Mr. Sprague.

*Early High-Tension Proposals.*—In a paper by the speaker before the Kansas City Electric Light Convention, in February, 1890, he made the following statement:

"As regards the potential, other things being satisfactory, whatever pressure is demanded in the interest of economical and effective service will be used; and means will be found, consisting mainly in care of construction, which will make its use for the purposes, and, as intended, safe and proper. We have, in these matters, to face the same questions that we have in the matter of steam pressure or of railway speed. To accomplish the larger engineering feats necessary to meet the demands of economy and commerce, we will be governed more by belief in our power to fully subordinate a good servant to our will than by our fears of its vagaries when allowed to become a master."

At the same time, to illustrate the possibilities of electric railway operation, the potential necessary to handle the then existing passenger service on the Philadelphia Division of the Pennsylvania Railroad was determined, the service being rearranged so as to permit of the dispatch of cars every 10 min. The supply was to be by direct current from a single overhead copper rod, 1 in. in diameter, over each track, with return through the rails. Among the solutions, it was found that with two stations 45 miles apart only about 1 800 volts motor potential was required.

It is a curious coincidence that now, sixteen years later, the proposal to use an overhead rod should be resuscitated, and also that the speaker's early proposal of a million circular-mil section of copper should be about the equivalent of the capacity of the special third rail now in use.

Mr. Mayer's proposal, however, is for a sectionalized soft steel overhead conductor, 1¼ in. in diameter, and of absolutely the worst known form for the transmission of alternating currents, for it offers the minimum area for unit cross-section, an impedance fully nine times the resistance of the same rod to direct current, and probably eighty to ninety times that of a copper rod of the same size to direct current.

Since the Kansas Convention, the speaker has often advocated the necessity of higher potentials, and is glad to say that, not only in alternating-current work, but in direct-current application his early prophesies, repeated a year ago with an expression of readiness to undertake the responsibility of direct-current installation at 1 500 volts, even on a third rail, have, by virtue of the developments of recent months, now been brought within the reach of practical accomplishment. This, under ordinary trunk-line conditions, would mean an increase of fully five times the distance between sub-stations common with 600 volts, and often even the possibility of their entire elimination.

*Working Conductors.*—Many difficulties would disappear were we in a happy age of wireless power transmission. We deal, however, not with dreams, but practical realities, and among these is the physical means of getting electric energy from a central station to the moving trains. The choice is limited broadly to two general methods, the overhead system in some form, available for both alternating and direct currents, and the third rail, available ordinarily only for direct currents. Mr. Sprague.

Mr. Mayer, after pointing out the shortcomings of present forms of trolley construction, if used for high-speed trunk-line operation, somewhat naively remarks that:

"As a very high and dangerous voltage must be used in the suspended conductor, it is essential to suspend it in such a manner that it will never come down."

The speaker fears that we have not arrived at that millennium in railway operation when collisions, with rearing equipment, and derailments, with consequent destruction of upright structures, are no longer among the possibilities; nor are we beyond the reach of sleet formation, especially on rigid structures, or the ravages of storms of various kinds.

Of course, quite aside from the matter of expense, all conductors necessary for bringing current to a train are objectionable in many particulars, and the points with regard to each were recently well stated by W. J. Wilgus, M. Am. Soc. C. E., at a meeting of the New York Railroad Club, about as follows:

The third rail offers certain hindrance to the ordinary maintenance of track, but overhead construction is inelastic, and the laying of additional tracks, or changes in grade and alignment require radical and expensive alterations in permanent overhead structures.

Derailments will crush one form of conductor to the ground, but may equally well knock down the supporting structures of the other and put all tracks out of service.

In wrecking, the third rail offers some obstruction to the throwing of the equipment to one side, but conductors overhead may interfere with the operation of crane booms.

With two or more tracks, snow cannot well be piled up between them when the space is occupied by third rails, but, on the other hand, overhead conductors are a source of danger to trainmen, and are subject to the troubles of sleet formation.

There has been much loose talk about third-rail troubles with snow and sleet, complications at frogs and switches, difficulties of current collection, and the danger to employees and trespassers. Extended operation has proven that many of these objections are largely overcome by a protected third rail, properly designed with due regard to clearance lines of equipment. On the other hand,

Mr. Sprague. with an overhead, 11 000-volt trolley, there is certainly danger to the public at overhead street and highway bridges, in tunnels and at low bridges because of the possibility of rearing equipment in case of derailment or collision, and because of the frequent physical necessity of the trolley being brought within a short distance of the cars.

There is, also, corrosion due to locomotive gases when steam and electric operation are maintained over the same tracks, and increased danger to men engaged in cleaning, painting, or repairing overhead structures in close proximity to high-potential lines.

Again, and this seems to be important on high-speed service, there is the possible interception of the train operator's view of the signals, because dips in the railroad grade may bring overhead bridges in front of the semaphores, which likewise may be made less distinctive when having truss members for a background. Nor can we ignore an increased element of danger to the men who have to maintain signal structures, and then there are the objections to exposed high-tension conductors certain to be raised by city authorities.

*References to Contracts.*—References to contracts where single-phase operation has been adopted are not always conclusive, and the inferences drawn may be misleading unless the circumstances are fully known. Some of those mentioned in this paper come in this class. The Sarnia Tunnel offered an opportunity for a manufacturing company to make a demonstration of the possibilities of operation by single-phase locomotives. The speaker is quite sure it will not be claimed, by engineer or manufacturer, that this equipment was not well within the possibilities of direct-current application, and it is certainly quite conceivable that the opportunity for first demonstration on a considerable scale had a financial value sufficiently tempting to the railroad company. As an offset to this, it can be stated that, on a similar problem, one set of absolutely comparative bids had demonstrated, for this particular class of work, a marked disadvantage for the single-phase equipment, both as to first cost and cost of operation.

On the London, Brighton and South Coast Railway it is true that a short section is to be equipped with quite another type of single-phase motor, but the reasons which have been publicly advanced, in so far as they are based on motor performance, are debatable, and if the speaker's information is reliable, the cost of installation will be a sorry criterion.

The New York, New Haven and Hartford Railroad project represents a different class of installation: the replacing of steam passenger locomotives by single-phase alternating-current locomotives supplied from an 11 000-volt trolley line. The adoption of this

Mr. Sprague.

equipment, under the particular conditions which exist, especially the use of a common terminal with the New York Central Railroad, which is to use another type of equipment, has been the subject of a good deal of discussion and some acrimonious comments, many of which have had nothing to do with the system *per se*.

The locomotives on both these roads are of the gearless type, and within a few months there will be opportunity for making comparisons of their performance—the New Haven representing the very latest single-phase developments, and the Central the embodiment of direct-current plans formulated nearly three years ago, and under the then existing limitations of 600-volt operation instead of the much higher potential now practicable.

Among other comparisons will be that of the physical construction and cost of the working conductors, the former using a protected under-contact third rail, and the latter an overhead double-catenary trolley carried on steel bridges spanning the tracks. Each is interesting in that each represents construction of that type which must be adopted to come within the classification of permanent, that is, of character equal to other parts of the road. A comparison is in order, because the construction proposed by Mr. Mayer will be at least as costly as that adopted on the New Haven road. It is an important fact that the unit cost per mile of track for the overhead construction is fully equal to, if it does not exceed, that for the third rail, despite the very high potential and the small size of the working conductor. It is proper to add that, no matter how high this potential, the unit cost of the conductor system alone, per mile of track, for this class of construction will probably not be reduced.

Another feature of the New York Central equipment cannot be compared to a like equipment on the New Haven road, because it does not exist on the latter, and that is the motor-car service, considered by many railway engineers and transportation officials, and applauded by Mr. Mayer, as one of the indisputably good reasons for adopting electricity for suburban service.

The former road is also equipped with batteries, largely because of insurance, and not as an actual necessity of operation. These could not be applied to a single-phase equipment without the introduction of motor-generator sets of the full capacity of the battery discharge, as an essential of supply from the battery to the line, which, in case of breakdown, would eliminate the battery from use; whereas, in the direct-current system, the intermediate machinery—that is, the booster—is simply for regulation, and is of only differential capacity, hence a fraction of the size of the others, and it is not essential to the supply of the current to the line in case of an emergency.

Mr. Sprague.

However, these two great systems will, of course, tell their own story, and after a reasonable length of service be influential in moulding decisions as to the future; but it is safe to say that, however ardently the most enthusiastic engineer may preach the beauties of economy, no great trunk systems, except for special reasons, as for example the urgent necessity of increasing capacity, will adopt electricity to save money until after the tangible results have been measured on these two roads. In fact, the probabilities are that, in any case, it will, to quote an official of an English road, be a case of spending money, not to save it because of economy in power, but to make it.

*Reasons for Adopting Electricity.*—There are but two broad grounds on which the adoption of electricity for trunk-line operation can be justified: First, because of such demonstrated economy, due to the generation of power at large stations and reduction in the cost of locomotive upkeep, as will more than offset the interest and depreciation of that which is essential to electric operation; and, second, the possibility of an increased service of a character which cannot be gotten in steam operation—such, for example, as the handling of trains at increased speeds, or moving heavier trains at satisfactory speeds because of a greater concentration of power, or the operation of frequent motor-car trains at high schedules in suburban districts and between important terminals.

Trunk-line service, however, presents peculiarities of its own, and its demands are responsible for a great awakening in the matter of higher potentials, which has led to many over-enthusiastic statements, and much discussion as to the merits of single-phase, polyphase, and direct-current equipments.

One thing is certain: higher potentials are necessary and possible. Another is that both motor-car combinations and locomotive-drawn trains must be used, the former necessarily, and the latter preferably under "multiple-unit" control.

Capacity of equipment is essential, and that more than economy. How is it to be gotten? Naturally, first by increase of individual equipment, and then, when this increase has reached its limit, by combining equipments; therefore the question of capacity will be briefly discussed.

*Limitations of Design.*—Neglecting for the moment the motor car, consider the simplest form of ordinary train operation: What is it that is to be replaced? Simply a steam engine; in other words, a motor supplied by a local boiler, furnace and coal bin, by another motor supplied through a wire by a bigger boiler, bigger furnace and bigger coal bin. It is not sufficient simply that these latter can be made of any desired size; in any case, they are intended to supply a number of motors. That which is essential, and in the

last analysis vital, is that the new motor shall not only have certain mechanical advantages, to the extent of eliminating the evils of reciprocating parts, but it must, above all, have capacity, measured not alone by torque or speed, but by both, and it must be of sustained character. Everything else is of tributary character. Mr. Sprague.

The designer of railway apparatus, whether for motor cars or locomotives, is handicapped by certain physical limitations which it is not within his power to change. These are determined by the gauge of the track, the size and number of drivers, the clearance under the motors, the length of rigid wheel base, the dead weight per wheel and the total weight per axle, to say nothing of such a trifling question as cost of construction; and it is his problem to provide within those limitations all the capacity possible.

It is just in this particular that the single-phase motor, despite an amount of experimental work, study and effort of the most persistent and able character, is sadly defective; and, as far as any present knowledge goes, its defects, while not prohibitive to the extent of making it an unworkable machine, are so inherent as to make it practically certain that, when compared with other kinds of electric motors, it is placed, individually, at a very serious disadvantage.

*Comparison of Motors.*—Of the three types of motors in use to-day in railway work, two—the direct-current and the three-phase motors—have a continuous rate of energy input, while the single-phase has an intermittent and variable rate. In the latter the attempt has been made to attain the results achieved by the variable-speed direct-current series commutator motor, despite the fact that there is combined in a single machine a motor and a transformer. Now, whatever the hopes of the engineering and railway world, it is necessary to deal with sundry tangible facts.

The first of these facts is, that the single-phase motor, when put to serious duty, and measured by identically the same rating and under like physical conditions, is only about half as good as the direct-current motor. Or, in other words, the weight of the complete electrical equipment, including motors, regulators and car-transforming apparatus, and with like physical limitations, is fully twice that required for direct-current—with, of course, a material increase in the mechanical equipment. It follows that the total weight of a single-phase alternating-current locomotive, to do the same service as a direct-current locomotive, will easily run from 40 to 50 tons more. The reason is simple; it is because of the heat generated on account of lower electrical efficiency, and the impossibility of working the fields of the motors at more than about one-half the magnetic flux.

Polyphase motors have the same advantage as direct-current

Mr. Sprague. series motors, in the matter of weight capacity, but are normally constant-speed motors, although it is possible to arrange for half and full speed, each of which is, however, a constant speed.

The speaker has made, and so have others, many independent investigations on this subject, and in the present state of the art the facts stated cannot be gainsaid. Therefore, it is somewhat astonishing to find Mr. Mayer, referring to certain machines, saying:

"These locomotives use high-voltage alternate currents, and have excellent speed regulation, giving practically uniform efficiency at any considerable speed, two advantages which far outbalance, especially for trunk-line traffic, their inferiority in other respects."

This latter is admitted as:

"Great weight per unit of power, limited capacity, high cost, and only moderate efficiency at any speed."

This description of inferiority is an unexpected indictment of the single-phase motor, and, considering a locomotive simply as a machine, he adds to this indictment by his criticism of the motor-generator type of locomotive, where a single-phase motor receiving current from the trolley line drives a generator which in turn supplies direct-current motors, concerning which he says: "Its complications, moderate economy, inevitably high cost, and great weight, are its serious drawbacks," in spite of its "excellent and economical speed regulation." As a matter of fact, the motor of such a combination can be directly supplied from a high-tension line, and the weight of this type of equipment is almost identical with that of a single-phase equipment, while it has some possibilities which the latter has not.

A practical illustration of the bearing of this difference in capacity is the fact that although the essential weight on the drivers of the New York Central machines is about 70 tons, instead of 85, as on the New Haven, the individual capacity of the former is so much greater that, with equal ventilation, fifteen of them will probably do the work of twenty-five of the latter.

Lack of capacity, however, is not the only feature wherein the single-phase motor fails in comparison with the direct-current machine. On large sizes, instead of two or four poles it has ten or twelve, and the series winding on the armature with two paths is replaced by one with as many paths as there are poles. The armature, in machines of similar capacity, has a larger diameter, and runs at a higher speed; and, instead of two fixed sets of brushes, there are as many movable sets as there are poles, to supply current to a commutator of larger size. The clearance between field and armature is about one-quarter that of the direct-current machine, and the allowable bearing wear, therefore, is much less. Finally,

the New York Central type of machine, with its remarkable mechanical as well as electrical advantages, is impossible to direct alternating-current construction and operation. Mr. Sprague.

It is curious to note with what persistency certain well-sounding statements reappear, in spite of frequent disproof. Among these may be mentioned that referring to possible economic variations of speed. With proper control, the ordinary four-motor locomotive operated on direct current has three impressed electromotive forces, for each of which it has a wide automatic range of torque and speed far beyond the limits, as the sustained torque increases, of the single-phase motor; and for each of these established conditions there is a very considerable range of speed with the same torque, provided the motors are properly constructed and controlled. The result is that, as every one of these speeds is an economic one, all variation essential for practical railroad operation is provided.

*Direct-Current Motor Improvements.*—Comparing the condition of the art at present with that of about two years ago, it will be seen that three important and radical developments have taken place in direct-current motor construction. The first is the use of the commutating pole, which, in a large measure, and certainly for any ordinary pressures, has eliminated the much abused bugbear of the commutator to such extent that, when properly constructed, it is impossible to tell by ordinary inspection whether a machine is running at high or low potential, or with large or small current, so absolutely free is it from sparking.

This has led to additional facilities in control, and the construction of motors for operation at from 1 200 to 1 500 volts, with the further possibility of operating two in series at double potential.

A third development is that illustrated by the New York Central gearless locomotives, in which the hitherto invariable practice of maintaining a fixity of relation between the armature, or rotating part, and the field magnet, or fixed part, has been abandoned, the armature being mounted directly on the axle, and the field magnets forming a part of the locomotive frame, supported by its springs and hence movable with regard to the armature. In this construction, therefore, there are no armature or axle bearings. This machine is one of the most remarkable and satisfactory outcomes of recent work, and, considering actual necessary electric additions to the mechanical equipment, it has, when designed for the conditions under which it should operate, probably the highest weight efficiency of any direct-current locomotive. Being of bi-polar construction, with a wide range of neutral brush contact, it runs practically sparklessly at all loads, is a natural 1 200-volt machine without commutating poles, and can easily be wound for a higher potential if using such poles.

Mr. Sprague.

In general, considering briefly the first cost of installation, it has been shown that the weight and cost of motor equipment are much higher for the single-phase alternating-current than for the direct-current system, and that the cost of permanent working conductors per mile of track is fully as high. The cost of the central station will be somewhat greater because of the reduced capacity per weight of material of single-phase generating apparatus. There remains the intermediary apparatus, when extended systems are considered, namely, static transformers and rotaries for the direct-current system, and sub-station and car transformers for the alternating-current system.

Unless there is material increase in efficiency and capacity of single-phase motor equipments, it is quite likely that the interest on the increased cost of sub-stations of one kind over that of the other, and the losses in the rotaries will be at least equalled, if not more than offset by the interest on the increased first cost and the cost of operation of the motor equipments on the alternating-current system, when each is installed with equal regard to permanency.

Every engineer, of course, hopes for, and will welcome actual advances in this art, by whatever system—everything, in fact, which makes for increased economy, added reliability and reduced cost of operation—to the end that there may be a greater extension of electric operation; but it is absolutely essential to compare results accomplished, not merely promises of performance.

Such are some of the general facts which must be confronted in dealing with the question of electric operation of trunk lines. In conclusion, the speaker will quote a remark by Chief Engineer Kando, of the Ganz Company, of Europe, the advocates of poly-phase motor operation, in a report recently made to his company after a trip in the United States. Referring to the question of equipment, he said:

"That system will prove to be victorious which can present the most powerful locomotive, and the locomotive which will possess the greatest capacity for a given weight."

The speaker might add to this, and say that it would seem that that type of locomotive must ultimately survive which has not only the greatest weight capacity, but also automatic response in torque and speed to the varying demands of grade and curvature.

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# PAPERS AND DISCUSSIONS.

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## THE ATCHAFALAYA RIVER: SOME OF ITS PECULIAR PHYSICAL CHARACTERISTICS.

### Discussion.*

BY MESSRS. HENRY B. RICHARDSON, T. G. DABNEY AND FRANK M. KERR.

HENRY B. RICHARDSON, M. AM. SOC. C. E. (by letter).—This paper, apart from its professional interest, merits special attention from those who remember the many diverse views and earnest discussion of what has been commonly referred to, in the Lower Mississippi Valley for the past quarter century or more, as "The Atchafalaya Problem." It presents, in condensed form, the results of recent surveys and brings to view features and characteristics of the stream that have heretofore received little notice. Mr. Richardson.

This "problem" has, perhaps, never been very clearly stated, and seldom twice alike. The proposed solutions have been naturally even more unlike than the statements of the problem. All, however, have sought in some way to improve one or all of the three streams involved—that is, the Red, the Atchafalaya and the Mississippi—either for navigation or for the prevention of destructive overflow. For instance, it has been proposed (1) to divert the Red from the Atchafalaya, either by turning it into the Mississippi some 20 miles above where it now enters, or at some one of several nearer places; (2) to close the Atchafalaya at or near its head, thus

*This discussion (of the paper by J. A. Ockerson, M. Am. Soc. C. E., printed in *Proceedings* for September, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Richardson.

cutting off its water supply from the Mississippi and the Red; and (3) to dam up the mouth of Old River (Fig. 2), thus divorcing both the Red and the Atchafalaya from all connection with the Mississippi, except for navigation through a lock at the head of Bayou Plaquemine and thence by the way of that bayou and Upper Grand River.

These general projects, with numerous variations, have each been strenuously advocated in the past, so that the subject-matter has well earned the popular title of a problem.

The last-named plan—that of divorcing the Red and Atchafalaya River System from that of the Mississippi—gives promise of most desirable results in the matter of protection from overflow; and now, that there is good prospect of an early opening of the lock at Plaquemine, through which navigation interests should be better served than at present, it may be expected that it will meet with increasing public favor.

The most serious objection ever urged against this plan has been prompted by the apprehension that the waters of the Mississippi cannot be successfully carried to the Gulf, between levees, below the mouth of Old River (or the head of the Atchafalaya) in such volume as they arrive there during great floods; and that for the security of the country below, along the Mississippi, the Atchafalaya must be left open as a safety-valve, or relieving outlet, for a part of the Mississippi flood waters. "Whether the banks and bed of the Mississippi River will accommodate themselves to the increased volume without undue strain," is, as the author remarks, "an important question."

While by no means settling this question, the fact that, at the times of the highest recorded flood stages in the Mississippi, at the mouth of Old River, the water surface has been at a still higher elevation at the head of the Atchafalaya, should throw some light on what would have been the situation if the two streams had then been separated. With the open channel, as it is and has been, there must have been at the times of highest flood referred to, a flow through Old River into the Mississippi, so that its flood volume, at the most critical moment, was increased instead of depleted. Of course, had Old River then been closed, this could not have happened; the water that was then tributary to the Mississippi could not have entered it, but would have found its way down the Atchafalaya to the Gulf of Mexico.

It is true that during the highest flood stages above mentioned the larger part, if not all, of the water that came through Old River to swell the floods of the Mississippi had escaped from it through breaks in the levee above, and was simply rejoining the stream it had earlier deserted. But the fact remains that in the times of

highest flood at the mouth of Old River, the Atchafalaya could not have acted as an outlet of the Mississippi, but quite the contrary. Mr. Richardson.

The building of a dam or embankment across the mouth of Old River, with a short extension connecting it with the adjacent levee lines, would close the only gap in the existing levee system on the right bank of the Mississippi below Amos Bayou ridge, in Desha County, Arkansas, and make it an unbroken line, extending practically from the Arkansas River to the Gulf of Mexico. With this gap closed, all overflow of the right bank of the Mississippi should be prevented. With it open—as at present—the waters "back up" through it in every flood, and annually inundate a wide area of land, sometimes several hundred square miles in extent, and often remaining for two or three months. The lands thus deluged are as fertile, and—except for their lack of protection against overflow—as desirable for cultivation and habitation as any in the alluvial valley.

Another objection to this plan has been, that, in case large crevasses should occur in the levees, permitting the Mississippi floods to invade the basin above the mouth of Old River, there might be such an impounding of water there as to cause deeper overflow than could take place with Old River left open. In other words, the Atchafalaya might not have sufficient capacity to discharge the water received from such crevasses fast enough to prevent its accumulation in so great a volume as to produce more extended inundation than would result from the "back water" alone with Old River open.

But the levees on the Mississippi have been, and are being, so constantly improved in height and strength that there should be less and less danger each year that there will be such crevasses; and the recent great enlargement of the Atchafalaya, described in the paper, should give some assurance that it will be able to dispose of all the crevasse water now likely to reach it. During the flood of 1890 its discharge was gauged near its head, and at one time found to be about 480 000 cu. ft. per sec. This is more than two and a half times the greatest measured discharge of the Red at Alexandria —that is, of Red River proper—and from this it appears that the Atchafalaya after receiving a maximum flood from the Red, still has room to take care of more than as much again from other sources.

The correctness of the author's conclusion that the confinement of the waters of the Atchafalaya, which formerly escaped over its banks, to a single channel by means of levees, is the chief cause of the recent rapid enlargement of its bed cannot be doubted. It seems probable, however, that the removal of the obstruction caused by the "raft" of 20 miles of floating trees and driftwood—referred

Mr. Richardson.

to in the paper—must have considerably increased the volume and erosive power of the water within its natural banks. But it appears still more probable that the strikingly rapid and irregular enlargement described must be principally due to the progressive confinement of its flood waters to one stream only, and the consequent concentration, upon its own bed and banks, of their scouring energies.

The physical characteristic of the Atchafalaya presented by the fact that it is deepest in places of excessive width is possibly peculiar to waterways which have undergone, or are undergoing, rapid enlargement, rather than to this particular stream. The instances illustrated in Plate LXI, and Table 1, are very interesting and are remarkable for the magnitude of the variations shown in the areas of adjacent cross-section. Similar irregularities in section, on a very much smaller scale, of course, may often be seen in ditches cut through rather stiff, but erosible, soil, when enlarged by the action of rapid currents; and it is not always easy to account for the numerous expansions, contractions and "pot-holes" found in them. Where the ditch is largest the scouring would have been greatest, and there the current velocities, in order to do the work, should have been highest. And doubtless they were so, though mostly indirect—whirling around in eddies—and entirely independent of the area of cross-section. Such eddies, both horizontal and vertical, are evident in most streams, and, when rapid and violent, seem sufficient to account for the formation of the holes and abruptly enlarged places, not only in small ditches, but also in the largest rivers.

Two instances shown on the charts of the Lower Mississippi River may be cited where extremes of depth and width are coincident: one opposite Ormond Plantation, about 28 miles above New

TABLE 3.

| Section. | Opposite Ormond. | | |
|---|---|---|---|
| | Width, in feet. | Depth, in feet. | Approximate area of cross-section, in square feet. |
| Wide section | 3 300 | 221 | 435 900 |
| Narrow section, 3 000 ft. above | 2 050 | 126 | 159 500 |
| Narrow section, 4 600 ft. below | 2 300 | 110 | 156 400 |
| | Near Old Quarantine Station. | | |
| Wide section | 3 000 | 248 | 372 900 |
| Narrow section, ½ mile above | 2 200 | 80 | 138 800 |
| Narrow section, ½ mile below | 2 450 | 137 | 189 600 |
| Narrow section, 2¼ miles below | 2 200 | 100 | 160 200 |

Orleans, and another just below the Old Quarantine Station, 5 miles above the Forts. Mr. Richardson.

The widths, scaled from the charts, the extreme depths, as shown by soundings, and the approximate areas of cross-section, at and near these places are shown in Table 3.

While the irregularities in form and area of section at these points are not so striking as those noted in the channel of the Atchafalaya, they show that extreme width and extreme depth may occur and persist together, even in a stream not undergoing rapid enlargement.

T. G. DABNEY, M. AM. SOC. C. E. (by letter).—It has been related that a student, when required to write a dissertation on the crab, described the creature as being "a red-colored fish that swims backward"; to which his professor replied that the definition was correct, except as to three particulars; "the crab is not red, is not a fish, and does not swim backward." Mr. Dabney.

Mr. Ockerson defines the "Atchafalaya River" as "an alluvial stream flowing between banks of its own formation"; to which it may be replied that it is neither a "river" nor an "alluvial stream" as defined above.

As to the latter characterization, the weight of geological authority has pronounced that the bulk of the material composing the so-called "alluvial valley" of the Mississippi River is not an alluvial formation, and was not transported and lodged where it now rests through the agency of the Mississippi River and its subsidiary channels, except as to superficial ridges or "natural levees" along the banks, thinning out to a mere "veneering" a short distance away.

The so-called "Port Hudson" formation which mainly occupies the basin, is pronounced to be a diluvial or estuarian deposit, brought from more northern regions by large volumes of glacial water, liberated by the melting and recession of the great "ice cap" in pleistocene time; antedating the present drainage system of the Mississippi Valley, which has incised its channels down into and through some of the older deposits.

This is not especially significant in the present discussion, however, as the "Port Hudson" deposits possess no greater resisting powers to current erosion, perhaps, than the more modern alluvium.

The writer attaches much greater potency to the first-named distinction, as bearing upon the subject under discussion. The term "river," as commonly understood, applies to a channel which receives all its water from the "run-off" of its own proper water-shed or drainage area. Its form and dimensions are the result of practically constant agencies which have operated for a very long time, by which practically stable conditions and regimen have been established.

Mr. Dabney.

The Bayou Atchafalaya is not a stream of that character, and is entitled to be called a river, if at all, only in a much modified degree, receiving the local "run-off" from a limited area on the western side for a portion of its length.

The bulk of its flood water comes from a wholly extraneous source, being delivered at its head by the Mississippi and Red Rivers, where its burden of 400 000 cu. ft. per sec. thus received must be the dominating influence in determining its character. It is a "bayou," a distributary, and not a river in any proper sense.

A marked characteristic of the Atchafalaya, which is a reversal of the rule of rivers, is that it probably carries a larger flood volume at its extreme head, than in its lower course where the low unleveed banks permit part of the flood to escape from the channel.

The burden thus imposed on the Bayou Atchafalaya was, as shown by Mr. Ockerson, rather suddenly and greatly increased by the removal of the obstructing rafts and the leveeing of its upper portion.

To those who are conversant with overflow conditions in the Mississippi bottoms, the phenomenon is the familiar one of scouring action induced by obstacles in the path of the flowing water, in consequence of vertical and lateral currents which are set up by obstructions, in a formation that yields readily to such destructive agencies.

When a crevasse occurs in a river levee at flood stage, the escaping water speedily scours out a deep hole or "crater" under the base of the levee and for some distance beyond the levee line.

These "crevasse holes" are familiar objects along the Mississippi River levee lines, are generally of large dimensions, and are locally called "blue holes" on account of their great depth, which gives a bluish, or rather greenish, tinge to the water, when in a state of repose. The occurrence of similar holes on a smaller scale, in situations remote from the river, is not unusual, as a result of obstacles encountered by the flood water, which set up scouring action. The writer has seen such a hole, "big enough to bury a church in," caused by a large stranded log, which, being over-topped by the flowing water, acted as a tumbling dam.

The sectional area of one of these great crevasse craters, when the water is flowing violently into and out of it, is much larger than that immediately above and below.

The whole content of this larger section, of course, is not moving in the general direction of the flow, with the same velocity as in the lesser entering and departing sections; nevertheless, the water moves with great energy in multitudinous diverse directions, vertical and lateral, which energy is expended on the bottom and sides of the crater.

It seems probable that in the case of the Atchafalaya a some-

what analogous action was set up in those reaches formerly occupied by the rafts, the bottom and sides of which are described by Mr. Ockerson as being "rip-rapped" by logs, remnants of the former rafts. Mr. Dabney.

These logs probably projected all sorts of ways from the bottom and banks of the channel, offering obstruction to the direct flow of the flood water, and affording ideal conditions for the generation of violent vertical and lateral currents, with inevitable scouring as the result, and a consequent deepening and widening of those parts of the channel.

The material thus dislodged was carried along down the channel, and probably deposited in the narrower intervening reaches, by which their depth was further reduced.

Here, as in the case of the crevasse crater, while great energy of movement was developed, it was not in the general direction of the flow of the stream, but expended itself on the bed and the banks of the channel. In the smaller sections all the energy of movement is utilized in passing the volume of water down stream, while a total of much greater energy of movement in the pools is largely dissipated in vertical and cross-currents.

To Mr. Ockerson's observation that in this case there appears to be a reversal of the law of rivers, by which narrowing the waterway increases the depth of channel, it may be suggested that the conditions described as existing in the Atchafalaya did not result from narrowing the waterway anywhere, but by the abnormal widening and deepening of the channel in certain localities through the operation of particular agencies present there and not elsewhere.

The deduction to be drawn from the foregoing is that the readiest way to enlarge a channel in this so-called "alluvial" formation, should be by placing partial obstructions in the path of the flowing water; and this conclusion is verified by observation; but whether such agencies can be applied and controlled so as to realize desired results is a more doubtful proposition.

The somewhat dogmatic tone of this "brief" is assumed for the sake of brevity. The writer, nevertheless, is modest enough to invite correction if any faulty positions have been taken.

FRANK M. KERR, M. AM. SOC. C. E. (by letter).—The past individuality, and present conduct, general characteristics and peculiarities, together with its relations toward the Mississippi and the Red Rivers, so interestingly described and ably discussed in this paper, no doubt single out the Atchafalaya River as, in many respects, distinctive from most other streams, in most other parts of the country, but hardly notably so in Louisiana. Mr. Kerr.

Mr. Ockerson says:

"Opinions differ as to its origin. It is probable that, at one time, it was the bed of the Red River which flowed directly to the Gulf of

Mr. Kerr. Mexico, but which was made a tributary of the Mississippi River by the elongation of the bend of the latter which cut into the smaller stream and made the mouth of the Red River near where it is now located. Even before this occurred the Atchafalaya portion served as an outlet for some of the overflow waters of the Mississippi River."

There is little or no question about the popularity of this opinion. However, there have been several other theories advanced, two of which it may not be uninteresting to recall.

The first of these may probably be more properly classed as a legend. But, however that may be, it would appear to possess sufficient ingenuity to merit resurrection in this discussion.

This theory, or legend, set forth that, in the earlier history of the valley, the Atchafalaya River had no existence at all, but, during a great overflow in the Mississippi River, it was given birth in the form of a breach occurring in the west bank of the Mississippi, at or near the point in the bend now known as Old River, through which the waters of the river rushed madly across country, by the shortest route to the sea, traversing the great network of small streams occupying that territory and lying in easterly and westerly directions, and cutting out the channel from the Mississippi to the Gulf of Mexico, later known as "Bayou Atchafalaya." In support of this it is shown, and is a matter of fact, that for every natural opening, or bayou, found on the right bank of the river, there will also be found practically throughout its length, almost directly opposite, on the left bank, a similar natural opening or bayou, as though the continuity of a succession of streams had been interrupted by some such "hop, skip and a jump" process, herein attempted to be described.

Next, there was the theory of Mr. Charles Ellet, advanced in a report made by him, under the auspices of the United States, in 1853, on the Mississippi and Ohio Rivers. Similar deductions will be found in the Report on the Mississippi River, prepared and submitted in 1861, by Messrs. Humphreys and Abbot, and in the report of the Louisiana Commission of Engineers (Caleb G. Forshey and M. Jeff Thompson), in 1873.

Mr. Ellet, in this report, in part, said:

"The Atchafalaya is by far the largest of the existing or former outlets of the Mississippi; and it has been often proposed to resort to its channel as the best and most efficient drain for the floods which now threaten the country below its source.

"In concurring with this popular idea, so far as to advise a commencement of the gradual and progressive enlargement of this great stream, it is not intended to represent the work as easy to accomplish, or in itself an effectual remedy for the floods of lower Louisiana.

"It will, in fact, be found to be an exceedingly difficult and costly undertaking, and one which will need to be conducted cautiously and not too rapidly, if it is to be effected without serious injury to the region through which the waters are to be conveyed. Mr. Kerr.

"The Atchafalaya leaves the old channel of the Mississippi about two miles below the mouth of Red River, and 310 miles, by the windings of the channel, above the Gulf of Mexico. It flows nearly in a southwardly direction; and when the Mississippi is swollen by floods, it serves as a natural vent for a portion of the present excess of waters, of which it bears off a large volume to the sea.

"At its source its average surface width in extreme high water is about 600 feet; its depth fifty-five feet; its slope six inches per mile; and its discharge not less than 85 000 cu. ft. per sec. It is about equal, measured by the area of its channel and the volume of water which it conveys, to one-twelfth part of the capacity of the Mississippi above New Orleans.

"It has long been supposed that the Atchafalaya was the ancient bed of Red River, when that stream had no connection with the Mississippi, but found its way to the Gulf of Mexico by an independent channel. The union of the two streams—the Mississippi and Red River—is accounted for, in this theory, by the supposition that, at the point where their waters now mingle, their channel then exhibited opposing flexures, and the current gradually cutting away the intervening soil, brought the streams together and made their waters common.

"This has become of late years a very popular theory, and is supported by several plausible arguments. The position of the mouth of Red River on the one hand, and that of the source of the Atchafalaya on the other; the direction by which Red River enters, and that by which the Atchafalaya leaves the old channel of the Mississippi correspond perfectly with the assumption that the curves of the two adjacent streams gradually approached, until they finally cut into each other. Besides, the color of the soil composing the west bank of the Atchafalaya at its source indicates clearly a Red River origin. But notwithstanding the plausibility and force of these facts, they are not at all conclusive, but apply with equal directness to another view that will be here suggested.

"In fact, the hypothesis which attributes the original formation of the Atchafalaya to the discharge of Red River is found, on a careful examination, to be wholly untenable. It results from actual measurements of the channel of these two rivers; that while the Atchafalaya at its source has a prevailing depth at high water, in mid-channel way, of only about fifty-five feet, Red River, at its mouth, only three miles distant, exhibits a depth of more than one hundred feet; that, while the Atchafalaya is confined within a channel less than six hundred feet wide at its surface, in high water, the width of Red River, between banks, a mile above its mouth, is more than 1 100 feet; and that, while the descent of the Atchafalaya at or near its mouth is six inches per mile, that of Red River, where it enters Old River, is at low water less than one inch per mile.

"The hypothesis of a former continuous channel, common to these two streams, so different in all their features, must, therefore,

Mr. Kerr. concede a sudden and remarkable change in the character of the supposed ancient Red River, at the precise point of the present junction of that stream with the Mississippi. Such a change, and the exact coincidence of that change with the point of accidental contact of the two shifting channels is, indeed, not impossible, but it is, at least, quite improbable. A less violent and much more satisfactory theory, to account for the existence of the Atchafalaya—one of the most remarkable features of the Mississippi—may be suggested, though the writer has not had full opportunities to submit it to a very rigid inspection.

"Black River, the proper continuation of the Ouachita, corresponds much more closely in the dimensions of its channel with those of the Atchafalaya than Red River. The general direction of the Ouachita is from north to south, corresponding well with the present general course of the Atchafalaya.

"The idea has impressed itself upon the mind of the writer, that in the original condition of the delta, the Ouachita, as well as Red River, descended by an independent channel to the Gulf, which then, perhaps, set up through a bay as far as the head of Lake Chicot.

"The Mississippi at that period pursued its present general direction. Red River had also its own independent channel to the Gulf, in the present Valley of the Teche, where it has left abundant traces of its course, in the composition of the soil and in the width and form of the immediate valley of the present stream from above the rapids at Alexandria down to Berwick's Bay. The Ouachita was thus an independent stream, descending to the sea between Red River and the Mississippi.

"According to this hypothesis, the Ouachita and the Mississippi, by the gradual approach of opposite bends, ultimately united their waters, and the Ouachita was, so to speak, cut in two—the northern part afterwards serving as a feeder to the Mississippi, and the southern end acting as an outlet for its surplus water in times of flood.

"The Ouachita having been a stream of smaller class than Red River, may be adduced as a reason why the present channel of the Atchafalaya, which was formed to accommodate the volume which that river, and not Red River, brought down, is insufficient for the discharge of the present volume of Red River. The Ouachita flowing directly down the plane of the delta, which it has been shown, descends at the rate of eight inches per mile, accounts for the greater fall of the Atchafalaya, which takes the same direction parallel with the dip of the same plane.

"Subsequently to the junction of the Ouachita and the Mississippi, Red River—then continuing on below Alexandria in the same southeasterly direction which it still pursues above that point—flowed over its natural levee, and, taking an easterly direction through the swamps, united its waters with those of the Ouachita at the present mouth of the Black River. Under this hypothesis, the increased volume below the confluence of these streams, in the course of thousands of years, may have produced the larger channel known as Red River, which even now is scarcely sufficient to accommodate their collected waters.

"According to this view, which is suggested as the most plausible explanation of the existence of the Atchafalaya, that stream was the ancient channel of the Ouachita, or its prolongation, Black River; and the present channel of Red River, below the mouth of Black River, was subsequently enlarged by the union of the waters of the Red and Black." Mr. Kerr.

In the foregoing, without going into other reasonings, the contrasts shown to have existed formerly between the section, slope and discharge of the Red and Atchafalaya Rivers, and the then practical agreement in all three factors between the Ouachita and the Atchafalaya, would appear to have given much color to the theory. The theory, however, is interesting not only in this respect, but, accepting the data, and comparing them with the facts furnished by Mr. Ockerson, not forgetting the shorter route to the sea, also in overcoming surprise at the irregularities and peculiarities of the area of section and slope in the Atchafalaya River, with its alternating wide and deep, and narrower and shallower reaches, and comparatively abnormal holes, here and there, found at this time.

Nor does the alarm then sounded about the possibility of the Mississippi River abandoning its own bed and taking such a route to the sea, leaving New Orleans, Baton Rouge and other cities inland, in the light of Mr. Ellet's statements and deductions, appear to have been altogether unwarranted.

Think of a stream in any soil, and particularly in a soil made up of detritus, from many sources at many periods in the history of the Valley of the Mississippi, with an unusually steep slope, whose high-water discharge, between banks, was in 1853, 85 000 cu. ft. per sec. (Ellet) accommodating itself in 1905 to a discharge, also between banks, or levees, of 400 000 cu. ft. per sec. (Ockerson).

That the "holes" demonstrated, by the recent survey under the direction of the Mississippi River Commission, to exist, are largely the result of levee building by progressive stages, confining the flood waters until they reached the ends of the levee, where, set free, with enormous local increase in slope, greatly increased velocities were created, and rapid whirls, eddies, counter and cross-currents were developed, attacking both sides and bottom, resulting in extraordinary conditions, is unquestionably true. Without the benefit of extended surveys, the writer had long ago accepted the existence of such conditions, from observations made on trips taken down the river in an ordinary skiff, during periods of high water. Traveling swiftly through the narrower sections of the river, the skiff would enter the wider sections with a pitch and a lurch, and meet such a combination of counter and cross-currents and eddies as would often produce the sensation of shooting the rapids. Imagine the effect, upon any irregular section of any stream, of a current velocity which would carry a craft, propelled by one ordinary oars-

Mr. Kerr. man, a distance of 26 miles in 3 hours. On the crest of the high-water wave of 1897, the writer made such a trip—from Simmsport to Melville—and the appearance of many of the eddies, at points in the river where the comparatively narrow reaches debouched upon the wider, was simply appalling; so that, though not fortified with the valuable statistical information now presented by Mr. Ockerson, the anomalies as to widths and depths of stream were, from observation alone, generally known and accepted long before his interesting study was taken up.

The effect of the struggle of the Atchafalaya River to get around and dislodge the extensive rafts known to have existed here and there within its bed, many of which the writer has seen and closely examined, must not be lost sight of, either, in accounting for the wider parts of the river and the consequent disturbance of regimen, tending to produce deep water in the wider reaches and shallower water in the narrower. Any stream undergoing the rapid development marking the history of the Atchafalaya must necessarily develop the apparent peculiarities, if not contradictions, pointed out by Mr. Ockerson, when compared with other streams of more orderly and deliberate action. The writer can also verify the author's deduction of the apparent relation between the volume of the flood to be carried and the cros-section of such a stream. This has been noticed by the writer, not only on the Atchafalaya River, but also on the Red River. Just as soon as the cross-section of a stream in process of development, such as in the Atchafalaya and Red Rivers, attains a certain uniformity of section, throughout a reach, caving often materially diminishes, if it does not actually cease.

The enormous increase in slope, at flood stages, near the ends of the levee lines confining the waters of the Atchafalaya, to which Mr. Ockerson calls attention, is notably true. So great is this increase at such times, that while ordinary steamboats can make fair progress up stream on that part of the river above the influence of the ends of the levee, at times barely any progress is possible for many miles below.

In 1897 the actually recorded high-water slope of the Atchafalaya River, from Simmsport to Scotland Plantation, 23½ miles below its head and within about 7 miles of the lower end of continuous confinement by levees on both banks, at that time, was about 0.54 ft. per mile. From Scotland Point to Melville, 7 miles, it was 1.1 ft. per mile.

It is not surprising, therefore, to find the deep, wide section given as No. 4 immediately below Scotland Point; and this is but one instance of the many that preceded and continued to follow the extension of the levee lines.

With each successive stage of extension of the levee system,

flood levels near the lower end are, primarily, materially raised, and an enormous increase of slope is created for some distance above the ends of the levees, precipitating the water into the unleveed portion below like a cataract, creating whirls, vertical, counter, and cross-currents and eddies, which could not but result in wider and deeper holes below than could, except under previous similar conditions in the progress of levee extension, prevail on the more regulated reaches of the river above. Mr. Kerr.

Nor is this peculiar in the Atchafalaya River. Similar, though possibly not quite as marked instances are innumerable on Red River, a stream which has also undergone and is still undergoing rapid development. Here, too, the influence of levees in enlarging and deepening the bed of the stream is probably more striking than in almost any instance in the world.

It is an undoubted and incontrovertible fact that on that part of Red River in Louisiana where, for some 15 years past, levees have been maintained, and the waters of the river have been regularly confined to the main stream, the width of the stream has almost uniformly more than doubled itself, and the increase in depth has been generally not less than 25 ft., and in places much more. When first confined, the plane of high water was in many places materially raised, but it is now decidedly lowering, there being apparent, in the last two or three high waters, a lowering of flood levels, of as much as 2.0 ft. along those parts of the river confined by levees.

The past relations of the Atchafalaya, and the Mississippi and the Red Rivers, are matters of history, and it is not necessary to lengthen this discussion further by reviewing them, but, as to its present relations, and their ultimate adjustment, much remains to be considered and said. There can be no serious division of opinion, however, as to the treatment necessary to bring about this ultimate adjustment, and the writer does not hesitate in placing himself on record as advocating that the Atchafalaya and the Red Rivers, in the proper course of time and events, should be divorced from the Mississippi. This would relieve and bring about equitable conditions in both those streams, where the influence of their relations is felt, and eventually result in improved conditions in the Mississippi, at and below what is called the mouth of Red River, as well.

Anyone who knows anything at all about high-water conditions on the Mississippi in the past knows that the highest stages of water at Red River Landing (on the Mississippi River, just below the mouth of Old River, more commonly, but erroneously, called the mouth of Red River) were brought about by a congestion of high waters at Barbres Landing, at the head of the Atchafalaya River, from the Red and the Mississippi Rivers, joined by crevasse

Mr. Kerr. waters from breaches in the line of public levee, on the Mississippi River, above the mouth of Red River, resulting in an elevation of surface at the point of conjunction, which brought about a reversal of slope and consequent tributary effect into the Mississippi.

If the line of public levee above the mouth of Red River be perfected and maintained, the divorcement of the Red and the Atchafalaya Rivers would, as a matter of course, result in a lowering of flood levels on the Lower Red River, and the Upper Atchafalaya, and, in the writer's opinion, if not at first, at any rate eventually, in the Mississippi River as well, in the vicinity of the mouth of Red River, with no material raising of flood levels below, that could not be readily taken care of.

The Atchafalaya, as an outlet to the Mississippi, is nothing more than a crevasse, tending constantly to deteriorate the body of the main stream below, as well as the connecting link between it and the Mississippi. The usual adjustment would undoubtedly follow the closure of the outlet or crevasse—rehabilitation of section, slope and velocity—and the much mooted and long discussed "Atchafalaya River Problem" relegated to the every-day treatment and control governing public work of similar character in the Mississippi Valley.

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# PAPERS AND DISCUSSIONS.

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## THE NAVAL FLOATING DOCK— ITS ADVANTAGES, DESIGN AND CONSTRUCTION.

### Discussion.*

BY MESSRS. GEORGE B. RENNIE, J. R. BATERDEN, CECIL H. PEABODY, C. COLSON, AND A. C. CUNNINGHAM.

Mr. Rennie.

GEORGE B. RENNIE, ESQ.† (by letter).—The writer's attention was first called to the subject of floating docks when Mr. Gilbert, of the United States, undertook the construction of a wooden dock for the Imperial Austrian Government, at the Austrian Naval Arsenal, at Venice, which, when completed, was towed to Pola. Having taken great interest in the construction of dry docks, his grandfather, John Rennie, having done much in that line, and his uncle, Sir John Rennie, having written a book on docks and harbors, it seemed to the writer that the wooden floating dock, as constructed by Mr. Gilbert, had many advantages over the docks formerly used.

On his return to England in 1852, he heard that General Quesada, Chief Engineer of the Spanish Navy, who had been to the United States and had seen the wooden floating docks in use at some of the naval arsenals there, had asked his firm whether such docks could be built of iron. As the writer had studied this question, he proposed an iron-plated floating dock for the naval arsenal at Cartagena, Spain. There was an excellent harbor at this place, but the shore was of soft rock with many crevices, etc., and, with much height and pressure of water, it was difficult to keep a dry

* This discussion (of the paper by Leonard M. Cox, M. Am. Soc. C. E., printed in *Proceedings* for October, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Member, Institution of Civil Engineers.

Mr. Rennie. dock tight. For this reason a floating dock was well suited for this harbor. It was then proposed to excavate a shallow basin in which to place the dock in order to clean and repair it, etc. This plan was carried out, and the writer understands that the dock has been there ever since—more than 40 years—and when he last heard of it was in as good condition as when new. It was, or is, 325 ft. long, 105 ft. broad, and takes a ship of 27 ft. draft on 3-ft. keel blocks; and lifts more than 4 500 tons. The Cartagena Dock was soon followed by one for Ferrol, Spain.

In designing these floating docks, many new things had to be considered and proposed; the iron structure had to be made to float, and the ends of the dock left out. The wooden docks were built with pontoons at each end; this arrangement allowed of docking a ship longer than the dock itself. The dock being in one piece, was very strong. Tests were made at Cartagena by filling any compartment and pumping it out, independent of any other compartment, and the dock was made to heel over sideways, as well as at the ends, and righted again without danger or difficulty. A more detailed and constructive account of this dock will be found in the *Minutes of Proceedings** of the Institution of Civil Engineers, and also in the *Transactions*† of the Institute of Naval Architects.

The iron dock for Ferrol was sent there, but was never completed, a revolution having broken out in Spain. The pieces of plating, etc., were used for other purposes. It was 50 ft. longer than the dock at Cartagena, and lifted nearly 1 000 tons more.

It may be mentioned that the bases of these docks were in single pieces riveted up, the means for cleaning and repairing being otherwise provided for. It was afterward arranged to have the bases divided into separate pontoons, so that the docks might be more easily launched, but where the base can be made in one piece it is better, as it is very difficult to connect the pontoons again after they have been in the water some years.

It is a satisfaction to the writer, after having constructed these iron floating docks for 50 or 60 years, to learn that so much interest is being taken in the subject, and that the docks have increased so much in number and size. This short account of what has been done may not be of much interest, but the writer is glad to learn that the subject is being taken up before the American Society of Civil Engineers.

Mr. Baterden. J. R. BATERDEN,‡ ESQ. (by letter).—The writer cannot admit that the cost of a graving dock is greater than the cost of a floating dock of equal capacity and in a similar situation. A comparison of the costs, when completed, of No. 3 Dock, Norfolk Yard, and the

* Vol. XXXI, p. 295.

† Vol. X, p. 17.

‡ Associate Member, Institution of Civil Engineers.

Charleston No. 1 Dock, leads one to the conclusion that the *Dewey* will have cost rather more than either of these. Mr. Baterden.

The writer's experience in the construction of a large number of graving docks is that in every case floating docks of equal capacity on the same sites would have been more costly. Moreover, in the confined situations to which docks and repairing yards have to be adapted in an industrial district where land is valuable, the floating dock, owing to the large amount of land taken up by slopes, in cases where dredging is required, often renders its adoption an impossibility from a paying point of view.

In one location where the writer had charge of the construction of graving docks, and where the water frontage was short and the work had to be carried on in a confined space, two graving docks were already in use, and another was being constructed, but, owing to high ground on three sides, and the soft nature of the foundation, it would have been impossible, without interfering with adjoining property, to have constructed more than one floating dock of a capacity equal to one of the graving docks.

In another place, however—a long narrow strip of land along the banks of the River Tyne—where two floating docks are in position, it would have been impossible to construct one graving dock of a capacity equal to the larger of the floating docks, without cutting up the yard in such a way as to detract seriously from its value.

These examples show that, as a general rule, each location has to be considered on its merits, one suiting a graving dock, another a floating dock. There are few situations, however, in which a graving dock could be built in fairly good ground, where the writer would recommend a floating dock.

As the author states, the expensive dredging which may be required, also moorings and shore connections, should be added to the cost of a floating dock for comparison with a graving dock, but in many cases this is not done. The dredging, which corresponds to the excavation required for a graving dock and much exceeds it in quantity, is in many cases a considerable item.

Judging by the photographs, one is led to assume that the *Dewey* is moored in deep water, and possibly no dredging was required, but, if dredging were done, it would be interesting to know the cost.

In the case of the two floating docks on the River Tyne, above referred to, the cost of dredging the site was about 14% of the cost of the docks, and was a long and tedious process, owing to the hard nature of the ground, in addition to which, the surrounding quays cost about 11 per cent.

The ideal site for a floating dock is where deep water is available close to the shore. If the dock has to be placed some distance out, in order to ensure deep water without dredging, then connecting

Mr. Baterden. jetties may have to be provided; otherwise, most of the material required for repair will have to be transhipped to lighters, taken to the dock, and lifted on board, thus being handled twice; whereas, in the case of a graving dock, it would probably be brought to the side by rail.

It is true that, except in rock, there is always an element of uncertainty about the foundations of a graving dock, which does not, to the same extent, enter into the calculations for a floating dock.

The element of risk to vessels in the latest improved floating docks is not a serious one, and it is known that accidents have occurred to vessels in well-equipped graving docks.

A floating dock can certainly be constructed in less time than a graving dock, but, if there is much dredging to be done, as in the instances above mentioned, and as in the case of the Bermuda dock, the time required might be much greater than the time occupied in building the dock, and even as long as in building a graving dock.

The depth of water required for floating docks of the capacity of the *Dewey* with a 30-ft. draft over 4-ft. keel blocks, would be more than 50 ft. Thus, it would be beyond the working depth of dredges of any power and capacity, and the dredging would have to be done by special means, which is always costly.

As the author says, if there be plenty of water under the bottom of a floating dock, one is not limited to the draft of ship taken on, as by the sill of a graving dock; but if dredging, especially of a difficult character, has to be done to obtain the necessary depth, it is unlikely that more than is absolutely necessary will be taken out, and the writer knows instances where the bottoms of floating docks rest upon the ground when sunk to receive a ship.

Unless it be confined by quays, a floating dock does not, like a dry dock, restrict the length of ship lifted, which is often a great advantage, but the advantage of adding sections to lengthen a floating dock when trade warrants, to which the author refers, is equally available by putting a temporary wooden end to a graving dock—not a costly item—and extending the dock when required.

The maintenance of floating docks is an item which, like their first cost, depends greatly upon circumstance, and there is not at present sufficient information to compare it accurately with the maintenance of graving docks, but it will be generally admitted that the latter is less. The dredging required from time to time, if the dock is in a location likely to be silted up, might be the larger proportion of the cost of maintenance (which may be anything up to 1½% per annum on the first cost, or more), and has the disadvantage of being more uncertain than the cost of painting and docking. If, as in the case of the *Dewey*, where no re-dredging enters into the cost of maintenance, it amounts to 0.72% per annum

on the first cost, it will be seen that if, as in places the writer knows, floating docks are in locations where silting goes on at the rate of from 12 to 18 in. per annum, the cost of maintenance might easily be doubled, because, with such excessive silting, dredging may be required more frequently than cleaning or painting. Mr. Baterden.

Again, in the comparison of maintenance between a graving dock and a floating dock, it must be noted that ordinary repairs could be executed and re-dredging done outside while vessels were in the graving dock undergoing repairs, whereas, in the case of the floating dock, for any dredging required, the dock has to be removed from the site, and in this case, as in docking and painting, the whole of the work is stopped.

As regards pumping, as far as the British Isles are concerned, with the high range of tides available, unless the graving dock be entered from a basin, or the ship be of the maximum capacity of the dock, the draft of ship regulates the quantity of water to be pumped, as ships can be admitted at different stages of the tide, some requiring more water than others; whereas, on the southern and eastern seaboard of the United States, for 1 500 miles or more, there is no appreciable tide, and on the remainder of the coast, east and west, the highest tides are only about equal to the lowest of those on the British coasts, and pumping would be much the same for all ships. Hence, in seas where the tidal rise is very small, the advantage of pumping is largely in favor of the floating dock.

The writer knows of no place on the British coasts where deep water, such as required by the *Dewey*, could be available except in a situation so exposed as to render it impracticable.

The moving of a large floating dock from site to site has so many objections that, from a commercial point of view, it could not be entertained. The loss of the floating dock while being towed from the Tyne to Durban, the grave fears which were entertained as to the safe arrival of the *Dewey* in the Philippines, the fact that these craft, with side area approaching the sail of a full-rigged ship, with the disadvantage of not being able to reef it, exposed to the action of wind and sea when being towed along a coast line or taken up rivers, the great cost of towing and insurance, however necessary it might become from a strategic point of view in time of war, must necessarily be very costly, and would entail the presence of a small fleet for protection.

It will be seen, then, that graving docks and floating docks each have their advantages; there is scope for both, and, in coming to a decision as to the selection of either, many things have to be taken into consideration.

CECIL H. PEABODY, ESQ.* (by letter).—This paper has the double interest that comes from a full description of the *Dewey*—the most Mr. Peabody.

* Professor of Naval Architecture and Marine Engineering, Massachusetts Institute of Technology.

Mr. Peabody.

important floating dock—and from a detailed statement of the computations for strength and stability. With such a wealth of computation, compressed as it must be for presentation in a paper of fifty pages, one can grasp at the first reading only the methods and general results, with perhaps a casual question or two. For example, on page 756,* the question arises: What was the distance from the keel to the bilge blocks? To be sure, a little puzzling over the figures leads to the conclusion that the distance must have been 22 ft. Again, the specifications require the dock to be able to dock all classes of ships, either centrally or with the keel 1 ft. off center, but no mention appears to be made of this in the calculation of the stability, nor is there any statement of the probable inclination of the dock under the assumed wind pressure of 30 lb. per sq. ft. As for eccentric loading, it is easy to see from Fig. 19 that a 16 000-ton ship, 1 ft. off center, will give an inclination of only $1\frac{1}{2}°$ in the worst condition.

One of the most interesting features of the paper is the discussion of the proper thickness of the outer shell plating. The author concludes that "all attempts to derive a rational formula for them in flat plates have resulted in complicated expressions too cumbersome for practical use," and, if he had it not in mind, would doubtless include in this category a paper by Ivan G. Boobnoff, I. R. N., "On the Stresses in a Ship's Bottom Plating Due to Water Pressure."† Truly, the computations required by his method, even with the aid of the special tables which he provides to save labor, would ordinarily be considered to be complicated, though it appears to the writer that too high a price can hardly be paid for computations which lead to reliable results.

It may be interesting to know that observations were made on the deflection of the rectangular panels of the inner plating of the double bottom of a certain warship, when tested under water pressure, by an assistant naval constructor who, at the time, was studying at the Massachusetts Institute of Technology. The results showed a fair conformity with the theoretical calculations made by Boobnoff's method. This work, which was under the direct supervision of Captain Hovgaard, Professor of Naval Design, it is hoped will be carried further and will be used as the basis of a logical determination of the proper thickness of shell plating, or the proper spacing of frames. Meanwhile the best practical guide is unquestionably the common practice in ship building, as given in tables of scantlings furnished by marine insurance companies and associations, or, as may be inferred, from practice in warship design.

The results of the experiments, referred to by the author on page

* *Proceedings*, Am. Soc. C. E., October, 1906.

† *Transactions*, Inst. of Naval Architects, Vol. XLIV, p. 15.

759*, will be awaited with much interest, though it is to be regretted that the plates were supported only at their edges and not continuous over the supports. Mr. Peabody.

C. COLSON, ESQ.,† (by letter).—A cardinal point presented for consideration by the author is whether there are advantages attaching to the floating dock which are of such a character and economic value as to outweigh those offered by the sunk or dry dock, both for commercial and naval purposes, but with special reference to the latter. Mr. Colson.

No question arises as to the possibility of designing a floating dock of dimensions, strength and stability capable of lifting the largest and heaviest ship constructed or contemplated. Recent examples of floating-dock construction conclusively prove this point.

There are places where the construction of a dry or sunk masonry dock would be, practically, an impossibility, or where it could be accomplished only at an enormous outlay; in such a case the only alternative would, probably, be the floating dock.

Among the many points to be taken into consideration with special reference to the floating dock are: Water area available in a convenient and sheltered position for berthing such a dock without obstructing navigation or interfering with wharfage; depth of water on any available area at low tide; draft of water required over the sill or keel blocks; character of the ground to be removed in order to obtain the depth of berth required; the class of vessel to be dealt with, and the use for which a dock is required; and, whether the depth of water over the keel blocks or sill should be for light or full-load draft?

Even for commercial purposes, it appears desirable that the power of docking at full-load draft at low water of spring tides should be available, although such a facility may not be often in demand. With regard to naval ships, not only is it essential that the power of docking at full-load draft at low water be provided, but there must be a margin of depth to admit of a seriously damaged ship being docked at low water. These requirements will increase the depth, and, consequently, the first cost and subsequent maintenance of the berth, and augment the ancillary works.

Where docking is required for cleaning and coating, or for the execution of minor repairs, the floating dock is eminently fitted, but, in cases where extensive repairs are required, involving the manipulation of heavy weights and the employment of a large number of men, the conditions become more complicated, and, in the writer's opinion, indicate the adoption of a dry dock, from the point of view that heavy weights can be handled with greater facility, resulting

* *Proceedings*, Am. Soc. C. E., October, 1906.

† Member, Institution of Civil Engineers.

Mr. Colson. in the saving of time and labor; further, a ship in a dry dock is under more complete observation from the wharf, and in case of fire is much more accessible.

With regard to the comparative cost of a steel floating dock and a masonry dry dock of equal docking capacity, there are so few data available as to the cost of the different items making up the complete installation, that any general statement must be fallacious; a reliable comparative estimate is only possible after careful consideration of the conditions obtaining in each case, and the preparation of alternative designs in detail. The total cost of installation should include the acquisition of the site of the berth and any other areas required in connection with the dock; the cost of the dock, complete; the conveyance from the place of construction to the permanent site; the preparation of the berth, moorings, shore facilities, including wharf walls or settees, shops, stores, etc.; and, means of communication between the dock and the shore. In this connection any information that the author can give as to the installation of the floating dock, *Dewey*, will be most valuable.

The time required to install a floating dock, complete in every particular, is not always determinable by the time required to construct the dock itself; it must depend greatly on the character of, and time required to complete, the ancillary works.

It is suggested that no land space is required in connection with a floating dock. This view will hardly hold good in all cases, or in the majority of cases, where a floating dock is required for cleaning and coating a ship and for minor repairs. It is conceivable that it might be moored in a position in the open, but even then it might be necessary to acquire the area of the harbor bottom for the berth. Where a dock is required in connection with an existing shore establishment, with water-frontage rights and wharfage, of course, a very considerable outlay will be avoided; but, failing any existing water and land facilities, a very substantial expenditure in this connection will be necessary.

The greater the width required on the floor, the greater will be the depth of the bottom member of the dock, and, consequently, the greater will be the total depth of the berth; while the area to be dealt with will be increased by the slopes necessary to ensure the stability of the sides, 59 to 60 ft. would not be an excessive depth below low water for a dock with a draft of 35 ft. over the keel blocks. This would probably mean the maintenance of a hole 24 or 25 ft. deep, below the approach channel; or, the bottom of the harbor, if the berth is to be located in deep water. The preparation of such a berth might be a long and costly operation, unless under very favorable circumstances. A site might be found with an ample depth of water at low tide, but such a case would be exceed-

ingly rare, and then only at a very inconvenient distance from the shore. Mr. Colson.

With regard to the author's remarks as to the comparative power of floating and dry docks, he must refer to dry docks constructed to take in ships of maximum draft at high tide only, or, at any rate, not at low water. In dry docks of modern construction the sills and floors, as a rule, are designed so that battleships of the greatest draft can be docked at low spring tide. Therefore, the advantage may be taken as being with the dry dock, inasmuch as the rising tide will increase the available depth of water over the sill or blocks. The exceptions to this are docks opening into a practically tideless harbor, or into closed basins where, however, the water, as a rule, can be raised 1 or 2 ft. by pumping.

A floating dock, when raised with a ship upon it, would be a very prominent target, and would be far more susceptible of damage from shell fire than a sunk dock. A suggestion is made that in an emergency the floating dock would have the advantage, inasmuch as it could be towed to a place, or places in succession, of greater safety. This, of course, would be possible, but does not the suggestion presuppose the provision and maintenance of emergency sites and moorings—adjuncts which cannot be prepared at very short notice even from a temporary point of view?

In the case of a badly damaged war vessel with a heavy list and all her weights on board, it is the writer's opinion that she would be placed with greater confidence in a dry dock than on a floating dock, because, in the former, the facilities for the removal or adjustment of weights, with a view to getting the vessel upright, would be greater than in the latter. It has been suggested, however, that the floating dock could be trimmed (*i. e.*, listed) so as to accommodate it to a listed ship, and the vertical position restored with the rising of the dock. This view is probably correct to a limited extent with a sectional dock, when dealing with vessels floating light—especially commercial vessels—and, to a greater extent, with the solid type of floating dock, but it is a doubtful point as to how far a heavy, deep-draft battleship with a bad list could be thus dealt with on a sectional floating dock, bearing in mind the character of the ship's bottom, the distribution of weights, and consequently the risks involved by insufficient or irregular support. In this connection it would be interesting if recorded details of any such operations could be quoted, and the opinion of the author and other experts would be of great value.

Although no doubt exists as to the possibility of lifting the largest and heaviest war vessel, under favorable conditions, there are risks and difficulties attending the docking operations on, and subsequent use of, a floating dock, which do not obtain in the dock-

Mr. Colson. ing operations, and subsequent use of, a dry dock. While the disabilities, by design, care in manipulation, and forethought, may be reduced to a minimum, they cannot be entirely eliminated. The balance of argument, therefore, remains in favor of the dry dock, especially for naval purposes. At the same time the writer fully concurs with the author's remark, "that each type has its own particular field of usefulness which the other cannot with advantage fill;" therefore, no thoughtful engineer will fail to recognize the value of the floating dock, or hesitate to recommend its adoption where the conditions undoubtedly indicate its adaptability in preference to a dry dock, although his bias may be in favor of the latter.

Mr. Cunningham. A. C. CUNNINGHAM, M. AM. SOC. C. E. (by letter).—Mr. Cox has treated the subject of floating dry docks so thoroughly and so ably, that there remains but little to say in the way of discussion which will not be a repetition of his ideas in a different form, or an enlargement upon the same.

The short and certain time in which a floating dry dock can be constructed may be an important factor, both from a commercial and a military point of view. From the actual records of the time of construction of various docks, and the observation of what might be the possible rate of progress of construction, it is safe to say, that, in emergency, a floating dock of the first magnitude could be built in a year. If such a dock was also of the sectional type, each part complete in itself, the time of construction might be still further reduced.

The possibility of manufacture in one or more places and of final assemblage and erection at the destination are also of great importance from the commercial and military points of view, especially from that of the latter. Since the trip of the *Dewey*, it is an established fact that a floating dry dock can be towed anywhere with certainty and safety. Such towing, however, is a slow and tedious operation, and in time of war would be attended with several apparent risks, all of which can be eliminated by the erection of the dock at its destination.

The British and Japanese Governments have just demonstrated that 20 000-ton battleships can be built in a few months. This is a demonstration that radical departures and advances in ship building may occur at any time in the future. When such departures and advances cannot be cared for with existing masonry docks, they are still rendered possible by floating docks. No matter what length, beam and draft may be given a ship, a floating dock that will accommodate it can be built and put in operation in less time than the ship can be constructed.

Increased and careful attention is being given to the docking of ships which may have abnormal draft from accident. To provide for

this contingency with a masonry dock means not only greatly increased difficulties and cost of construction, but a continuously increased cost of maintenance, and more especially operation. Mr. Cunningham.

The floating dock is an ideal structure for dealing with ships at abnormal draft. Its increased cost for this condition is a trifle; there are no increased difficulties of construction; the increased cost of maintenance is hardly perceptible; and, the cost of operation for ordinary conditions is not increased at all.

While the desirability of a floating dock for dealing with ships at abnormal draft is becoming recognized, general attention has not yet been called to its possibilities as an auxiliary to masonry docks for this condition. The masonry docks of the future must accommodate the length, beam, and normal draft of the ships which they are to dock, but if they are to accommodate also the possible abnormal draft which may occur, it means a large and constant outlay of money for which there will seldom be a return. From a military point of view, abnormal drafts will occur in groups at unknown intervals, and may be with our own or captured ships.

With a suitable distribution of floating dry docks, the provision for abnormal draft in masonry docks may be dispensed with, and the increased first cost of constructing and the continual excess cost of pumping avoided. With such a combination the ship would be lifted first by the floating dock, such temporary repairs would be made as would restore normal draft, and the ship would then be placed in the masonry dock for complete and final repairs. At first thought it would seem that one deep-draft masonry dock in a suitable group would fully meet the requirements, but the mobility of the floating dock again introduces special advantages. Abnormal draft, in any event, means a dangerous condition, and may mean that a ship cannot pass through a harbor or regular channels in order to reach a masonry dock. In such an event the floating dock can go to a place where the ship can be lifted, and, as the draft of the combination will be small, the combination of dock and ship can be towed to a place of shelter and safety. One important requisite in docking a ship in a floating dock is that there shall be no independent and uncontrolled vertical motion in either. In extreme cases, however, as the saving of a battleship, even some vertical motion might be safely risked by suitably padding the deck of the dock with timber.

Floating docks located at the entrance of New York Harbor, the mouth of the Delaware River, the entrance to Chesapeake Bay, and in the Harbors of San Francisco and Puget Sound, might, in saving one or at the most two battleships, more than return the cost of all the docks together.

A floating dock in connection with a floating repair plant con-

Mr. Cunningham.

stitutes a repair station that can be taken anywhere. The repair plant can also be in the form of barges which can be placed on the deck of the dock when a move is desirable.

As to convenience and accessibility in use: If a floating dock is moved into a slip after lifting a ship, the bottom is more accessible to workmen than in the case of a masonry dock, and, with a suitable gantry crane, everything movable on the ship can be handled more conveniently and safely than with the jib cranes used around a masonry dock. With a suitable depth of water in the slip this same gantry crane would be far more desirable for handling the heavy weights on ships that are not docked than the shears and jib cranes now generally used.

In the matter of possible accident the floating dock, theoretically, is more exposed than the masonry dock. In this matter, however, every dock, whether masonry or floating, must be judged by its special conditions. A masonry dock, however safe and perfect in other respects, may always have its caisson rammed, and, with a ship in dock, such an accident would be very serious. A floating dock in an entirely exposed position may be rammed from all sides, but, if empty, such an accident would not result in the loss of the dock, on account of the very numerous water-tight compartments, and, for the same reason, if a ship were in the dock, the damage to it is not likely to be as great as in the case of the rammed caisson of a masonry dock. If a floating dock is placed in a slip with a level bottom not much below the bottom of the dock, ramming from any very heavy ship is impossible, and any serious sinking from failure of valves is guarded against. Floating docks are entirely free from failures of foundations due to quicksands, springs, and the hydrostatic pressure to which all masonry docks are more or less exposed. The caissons of masonry docks may fail from other causes than ramming, and, in the case of an isolated dock having no spare caisson, such a failure might put the dock out of commission for several months.

For certainty of preservation and repair, it has been necessary so far to make steel, floating dry docks self-docking. This feature not only complicates the construction and increases the cost, but is a source of more or less weakness, according to the number, location, and complication of the joints which connect the various parts of the dock. To eliminate the self-docking feature, the writer proposes an independent caisson for the repair and preservation of the bottoms of solid docks, which, if it can be made effective, will simplify the floating dock problem.

The proposed caisson is illustrated in Fig. 21, which is diagramatic, and for purposes of explanation only.

The action of the caisson is as follows: Caisson floating light

Mr. Cunningham.

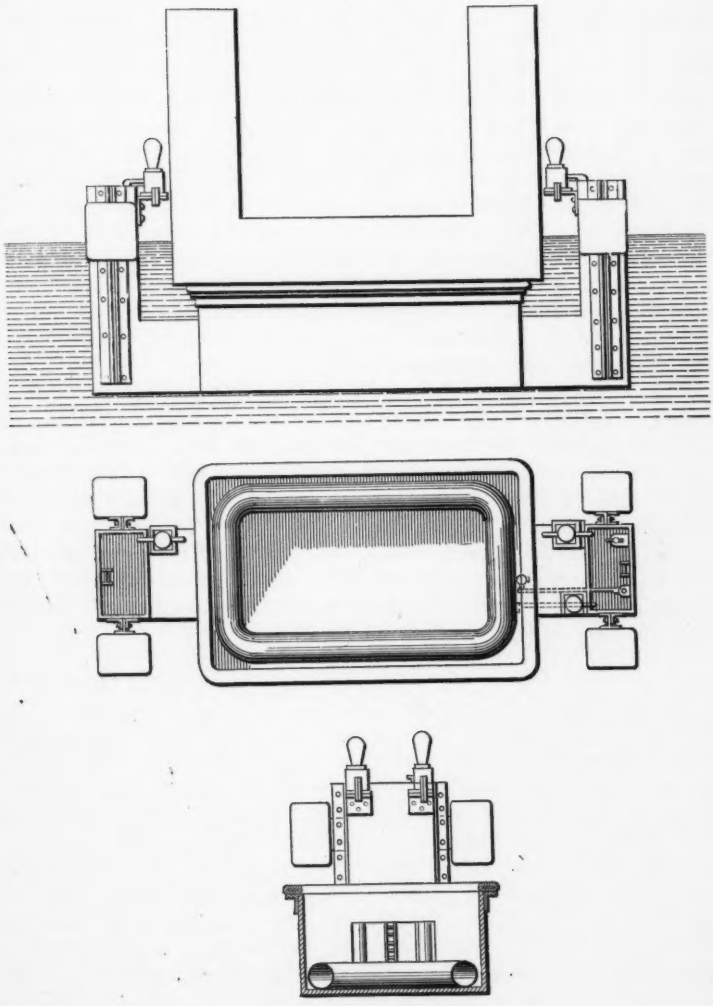


FIG. 21.

Mr. Cunningham.

with main and supplemental chambers empty; main chamber opened, and water freely admitted; complete submergence is prevented by the supplemental chamber. Water is next admitted to the supplemental chamber until buoyancy is just destroyed; the caisson then sinks until arrested by lines or supplemental floats. In this condition the caisson is moved under the bottom of the dock. Expelling the water from the supplemental chamber causes the caisson to rise and seal against the bottom of the dock; the water is next expelled from the main chamber, causing a still firmer seal against the bottom and providing a space in which work may be performed. The edges of the dock may be worked on by canting out of the water, or the caisson may be sealed against the bottom with the supplemental chamber and with one end projecting; after the edge of the dock is canted out of the water, the main chamber may be emptied; a working platform is thus provided. It is evident that entrance shafts and supplemental floats are not essential, as the caisson could be controlled by lines, and access had through a manhole in the bottom of the dock after the caisson was sealed.

If the self-docking feature of floating dry docks can be eliminated, a valuable gain will be secured. Not only do self-docking features increase the cost and complication of a dock and cause weakness on account of the necessary joints, but the self-docking of itself causes a loss of valuable time which, at least, may amount to from one to three months.

If a successful caisson method can be devised for working on the bottom of a dock, no time whatever need be lost unless it is in working on the edges of the dock, and, furthermore, it will be possible to carry on work while a ship is in the dock.

# MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

## WILLIAM THOMAS PIERCE, M. Am. Soc. C. E.*

DIED FEBRUARY 26TH, 1906.

William Thomas Pierce was born at Leominster, Massachusetts, on February 12th, 1854, and died at Watertown, Massachusetts, on February 26th, 1906, of a complication of troubles, a valvular difficulty of the heart being the immediate cause of death. He was one of four sons of John Q. A., and Elizabeth C. Pierce, the others being named Charles Q., Henry B., and Myron E.

He received a public school education only, and his life is a good example of what a man can accomplish in America by constant and continuous effort toward a definite end. At the age of sixteen he decided upon a professional career, and chose engineering as his life work, entering the office of Ernest W. Bowditch, Landscape Gardener and Engineer, of Boston, Massachusetts, to begin at the bottom of the professional ladder.

He was always a close observer, a great student and an incessant reader, and rendered his professional studies more than usually valuable by a habit, early contracted, of card-indexing current engineering magazines, reports and textbooks. His indefatigable industry resulted primarily in his great proficiency as an engineering draftsman, and some of his pen and ink drawings turned off in the 70's might even to-day be used as the best types of that class of work.

In 1880, with the full approval and cordial co-operation of his employer, he obtained a position on the engineering force of the Mexican Central Railroad, then under construction, in which position he not only gained experience in railroad construction but familiarity with the running of preliminary and location lines. In accepting this position he was able, not only to add materially to his professional knowledge, but to broaden his general experience.

Two years later, he undertook certain preliminary and location surveys for a railroad near Quebec, Canada, expecting to be employed later on construction. In this, however, he was disappointed, the parties having charters for the roads being unable to make satisfactory financial arrangements. In 1885 he returned to Boston and re-entered the employ of E. W. Bowditch, as a First Assistant Engineer.

For the next few years most of his time was devoted to prepar-

* Memoir prepared by Ernest W. Bowditch, Jun. Am. Soc. C. E.

ing schemes and superintending the construction of sewerage works; and Bar Harbor, Maine, and Waltham and Newburyport, Massachusetts, show the results of his care and foresight. His ingenuity and fertility in resource, about this time, were shown in the development of many original methods of pipe sewer construction and testing materials—methods which have been adopted since then by many members of the profession.

In 1893 he decided to establish a private practice where he could be more independent than was possible in a salaried position, and where he could undertake, within reasonable limits, such original investigations as he chose, without interfering with duties which had a right to claim his time. Almost immediately, however, he was appointed Superintendent of Streets, in Watertown, Massachusetts, where he lived. He retained this position until he was selected as Chief Engineer of the Metropolitan Park Systems in Boston, which post he filled until 1903, when he felt obliged to resign, owing to ill health. While in the Park employ, he was, naturally, so fully occupied that he was unable to give any time to private practice, excepting in a very limited way as a consulting engineer, so that this attempt to establish private practice proved abortive.

After retiring from the position of Chief Engineer of the Metropolitan Parks, he still continued his interest in the work of the office he had organized, and retained this until the very end, in February, 1906.

The Metropolitan office, when he took charge, was newly organized, or, rather, he organized it, systematizing the methods of keeping note and calculation books, plans, etc., so that any work, whether current or otherwise, could be easily and quickly referred to without loss of time. A detailed system of progress reports on each and every piece of construction, in a form devised by Mr. Pierce, which reports were filed periodically in the main office, not only rendered it possible to study intelligently any work either completed or in progress without being obliged to confer with the assistant or assistants having charge, but proved of inestimable value in case of dispute with contractors over payments for work, allowances for extras, and the like.

Besides this, detailed daily reports were made on construction, which were signed once each week by both contractors and inspectors. This simplified the final adjustment of any and all claims for extras and allowances, and made unnecessary the usual discussion and division on ambiguous clauses of contracts. For, when discussion is delayed until the completion of the work, after many matters of detail may have been forgotten, these frequently cause delay and sometimes lawsuits before settlement. Such reports would scarcely be practicable in the daily business routine of a private office, but, in a public office, such system and detail must prove, not only possible, but very desirable.

Though high-strung and impatient, he had himself thoroughly under control, and, even at times of great provocation, seldom allowed himself to be caught unawares. Early in his professional life he adopted as a mental safety valve the scheme of writing out his first impressions, if pleased or annoyed by people and things. This statement he would put under his pillow at night, and almost always the next morning he was ready to modify his statements of the previous day. Later in life, he changed this practice and usually expressed no opinion whatever until he had slept on it.

Professionally, it may be said of him that he was successful to a marked degree; that he was a good workman who knew how to use his tools to best advantage, and was intolerant alike of slovenly or careless work in others.

Upright and honest in his dealings, methodical, persistent, conscientious and resourceful with his work, he was a man who had not only the entire confidence of his employees but, what is quite as important and less common, the good will of the laboring men and contractors with whom he came in contact.

In August, 1903, on account of his physical disabilities, he practically withdrew from active work, and, from that time until his death, he was scarcely ever entirely free from pain and discomfort. Even through his last sickness he remained cheerful, and ready to look on the bright side of everything, paying no attention to his own physical infirmities, and always interested in the latest engineering work, whatever it might be.

He was elected a Member of the American Society of Civil Engineers on December 5th, 1894. He was also a member of the Boston Society of Civil Engineers, the Middlesex Club, the Boston Club, and the Boston Athletic Association.

In 1883 he married Almira P. Goss, of Salem, Massachusetts, who, with one daughter, survives him.

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## ELVER LA ZELLE SHINBUR, Assoc. M. Am. Soc. C. E.*

DIED NOVEMBER 7TH, 1906.

Elver La Zelle Shinbur was born at Oakland, Nebraska, on April 3d, 1879. He received his early education at the home schools and at the Omaha High School, attended the University of Nebraska from 1897 to 1901, and received the degrees of Bachelor of Science and Civil Engineer from that institution.

During the summer of 1901 he was employed as instrumentman on grading and viaduct construction in South Omaha, Nebraska,

* Memoir prepared by C. R. Thompson, Esq., U. S. Reclamation Service, Mitchell, Nebraska.

for the Fremont, Elkhorn and Missouri River Railroad. In the fall of that year he left railroad work to go to Cuba, as Topographer under the United States Military Government, where he had charge of from four to seven reconnaissance parties engaged on a military survey of the Provinces of Puerto Principe and Santa Clara. Upon the termination of the control of the island by the United States, Mr. Shinbur was made Assistant Engineer on preliminary and location surveys and construction for the Insular Railroad Company, of Havana. After remaining with that company for a year, he went to Mexico as Resident Engineer on construction with the Vera Cruz and Pacific Railway, having charge of concrete and stone masonry, the erection of steel bridges, etc. From August, 1904, to the date of his death, Mr. Shinbur was with the United States Reclamation Service. During the autumn and winter of 1904-05 he was assigned to the Uncompahgre Valley Project, in Colorado, where he had charge of four field parties engaged in topographic work and location. In March, 1905, he was appointed Assistant Engineer in the Reclamation Service, and since April of that year was in charge of the construction of the second 50 miles of the Interstate Canal, in Wyoming and Nebraska, with headquarters at Mitchell, Nebraska.

While in Cuba, Mr. Shinbur met Miss Anna M. Leland, of Ann Arbor, Michigan, whom he married in October, 1905. They had been married scarcely a year when he contracted typhoid fever and, after a short illness of ten days, died at his home in Mitchell.

Mr. Shinbur was eminently successful in all work upon which he was engaged, and was spoken of by his superiors in terms of the highest praise. In manner always quiet and reserved, he had gained the respect and affection of the men under his direction and of all those who came in contact with him. It seemed particularly sad that this young man, after earning promotion by hard work and devotion to duty, should be stricken down when the future was so bright before him.

Mr. Shinbur was elected an Associate Member of the American Society of Civil Engineers on October 3d, 1906.